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Central Long Island Sound Disposal Site
June 1991

Disposal Area Monitoring System DAMOS

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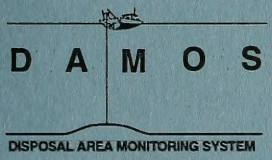

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13. ABSTRACT *(MAXIMUM 200 WORDS)*

Science Applications International Corporation (SAIC) conducted a monitoring survey at the Central Long Island Sound (CLIS) Disposal Site from 18 to 23 JUNE 1991 as part of the DAMOS (Disposal Area Monitoring System) Program. The objectives of the June 1991 field operations were to map the distribution and thickness of the dredged material in the areas that received project materials after the 1990 DAMOS survey (CLIS-90 and CS-90-1) and to evaluate the status of inactive mounds: MQR, NHAV-74, CLIS-88, CLIS-89, CS-1 and FVP. Surveying and monitoring techniques included precision bathymetry, REMOTS sediment-profile photography, CTD and dissolved oxygen information, and sediment grab samples.

In September 1990, the CLIS disposal buoy was deployed at 41°9.212'N, 72°53.25'W. Barges released approximately 59,000 m^3 of dredged material at this location between September 1990 and May 1991. It was predicted that a new disposal mound would form at this location. During the 1989/1990 disposal season, barges released 8,730 m^3 of additional dredged material at CS-90-1 to increase cap thickness.

The precision bathymetric survey detected a small, newly formed disposal mound at the CLIS-90 buoy location. The addition of 8,730 m^3 of material to the CS-90-1 was detectable in the bathymetric survey as two 20cm thick areas of accumulation. REMOTS sediment-profile photography detected the presence of dredged material at all stations within the survey area. "Fresh" or recent dredged material, identified by sedimentary fabric and shallow apparent RPD (Redox Potential) depths, was several hundred meters away from the active mounds. The limit of the dredged material mound, as mapped acoustically, was within a 100 m radius of the CLIS-90 buoy location.

Benthic recolonization was deterimed from analysis of REMOTS photographs obtained at CLIS and at three outlying reference areas. Recolonization predictions from the DAMOS tiered monitoring and management protocol were that the active mounds should be in a Stage I sere while Stage III sere should colonize the inactive mounds: MQR, NHAV-74, CLIS-88, CLIS-89,CS-1, and FVP. The 1991 REMOTS data supported these predictions.

Water column profiles of temperature, salinity, sigma-t, and dissolved oxygen were determined on June 18th at the CLIS-90 buoy and three reference areas. The water column at these four sampling stations was stratified with respect to both temperature and salinity. Dissolved oxygen (DO) concentrations below the pycnocline were 6 to 7 ppm, 2 to 3 ppm lower than near surface values. DO values were similar between the CLIS-90 buoy location and the three reference locations.

Sediment samples collected from the CLIS reference areas contained metals in similar low concentrations as measured during previous CLIS surveys. Polyaromactic hydrocarbons (PAH's) were also analyzed to provide a baseline for future sampling. PAH's were measured at all three reference areas in concentrations generally within ranges present in regional Long Island Sound.

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1.0 INTRODUCTION

The Central Long Island Sound Disposal Site (CLIS) is located approximately 6 nm south of New Haven Harbor, Connecticut (Figure 1-1). Environmental monitoring by the U.S. Army Corps of Engineers, New England Division (NED) has occurred at the site since 1972. A primary objective of past investigations has been to assess the environmental impact of dredged material disposal, particularly the postdisposal recovery of benthic ecosystems. A secondary historical objective has been to monitor the location of dredged material, the height, areal extent, and stability of the dredged material mounds, and postdepositional dispersion of material.

Several active and inactive disposal mounds currently exist at CLIS (Figure 1-2). The previous monitoring survey at CLIS, conducted in July 1990 (Germano et al. 1993), monitored the disposal activity occurring at CLIS between 1988 and 1990. Results from the July 1990 survey included the detection of the CLIS-88 and CLIS-89 disposal mounds, as well as the small capped mound, CS-90-1.

During the 1990/91 disposal season, 67,730 m^3 of dredged material was disposed in the northwest quadrant of CLIS. Barges released most of this material (59,000 m^3) at the CLIS-90 buoy. Approximately 8,730 m^3 was additional cap material placed on the CS-90-1 mound. The CLIS-90 buoy and CS-90-1 were the only two disposal locations to receive dredged material between the July 1990 and the June 1991 surveys.

SAIC conducted the field operations at CLIS from 16 to 23 June 1991. The field work consisted of a precision bathymetric survey, Remote Ecological Monitoring of the Seafloor (REMOTS®) sediment-profile surveys, dissolved oxygen (DO) and conductivity/temperature/depth (CTD) profiles, and sediment sampling for polynuclear aromatic hydrocarbons (PAHs), grain size, and total organic carbon. The objectives of this study were

1) to delineate the footprint and topographic elevation of dredged sediment deposited at the CLIS-90 buoy location since the July 1990 Disposal Area Monitoring System (DAMOS) survey by means of a precision bathymetric survey and sediment-profile photography;

2) to determine the successional status of mounds that have received dredged material since September 1990 (CLIS-90 buoy location and CS-90-1 mound capping) and to monitor conditions at the inactive mounds CS-1, CLIS-88, CLIS-89, NHAV-74, FVP, and MQR. The results were to be used to test hypotheses and predictions that form part of the DAMOS tiered monitoring and management protocol;

3) to measure near-bottom and near-surface dissolved oxygen concentrations and vertical profiles of temperature and salinity at the CLIS-90 buoy location and reference areas to evaluate the potential role of dissolved oxygen for explaining observed differences in organism-sediment properties between the disposal site and the three CLIS reference areas; and

4) to collect additional PAH baseline information at the three reference areas.

The 1991 monitoring program at CLIS tested the following predictions:

- Sediment disposed since September 1990 would result in the formation of a mound with a radius of 200-250 m.

- Benthic recolonization at CLIS would be mostly in Stage I on the recently capped CS-90-1 mound and CLIS-90 buoy mound. The inactive mounds were predicted to be mainly in a Stage III condition.

- Near-bottom dissolved oxygen concentrations would be high (and comparable) at both the disposal site and the three reference areas.

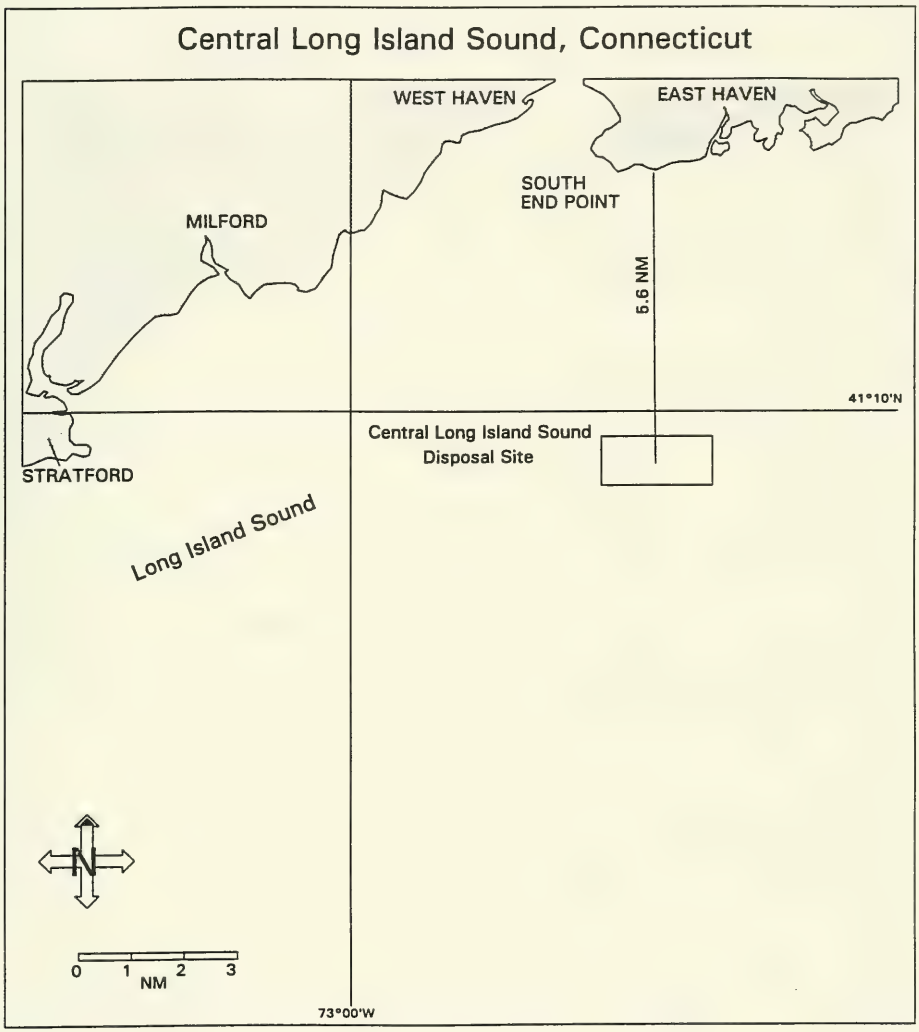


Figure 1-1. Location of the Central Long Island Sound Disposal Site (CLIS)

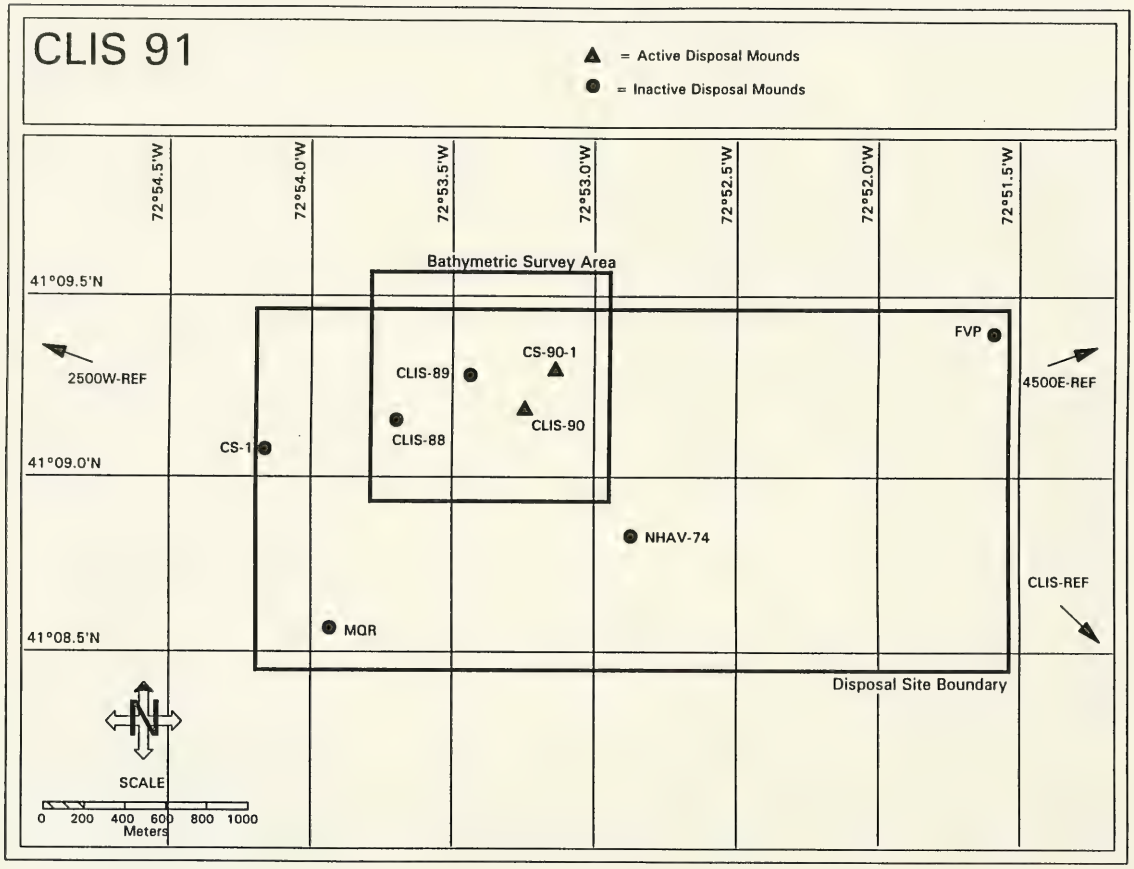


Figure 1-2. Locations of the surveyed active and inactive disposal mounds and the bathymetric survey area at CLIS, June 1991

2.0 METHODS

2.1 Bathymetry and Navigation

The SAIC Integrated Navigation and Data Acquisition System (INDAS) provided the precision navigation required for all field operations. This system used a Hewlett-Packard 9920® series computer to collect position, depth, and time data for later analysis, as well as provide real-time navigation. A Del Norte Trisponder® System provided positioning to an accuracy of ± 3 m. Shore stations were established in Connecticut at known benchmarks at Stratford Point (41°9.112′ N and 73°6.227′ W) and Lighthouse Point (41°14.931′ N and 72°54.255′ W). DAMOS Contribution #60 (SAIC 1989) contains a detailed description of the navigation system and its operation.

An ODOM DF3200 Echotrac® Survey Fathometer with a narrow-beam 208 kHz transducer measured individual depths to a resolution of 3.0 cm (0.1 feet) as described in DAMOS Contribution #48 (SAIC 1985). Depth values transmitted to the computer were adjusted for speed of sound and transducer depth. Before starting the 1991 precision bathymetric survey, a Seabird Instruments, Inc. SEACAT SBE 19-01 CTD probe was used to calculate a sound velocity profile. During analysis, raw bathymetric data were standardized to Mean Low Water by correcting for changes in tidal height during the survey. A detailed discussion of the bathymetric analysis technique is given in DAMOS Contribution #60 (SAIC 1989).

The June 1991 bathymetric survey of the northwest corner of CLIS encompassed a 1200 × 1200 m grid centered at coordinates 41°9.260′ N and 72°53.353′ W (Figure 1-2). The survey consisted of forty-nine lanes run east and west at 25 m lane spacing.

2.2 REMOTS® Sediment-Profile Photography

REMOTS® photography was used to detect the distribution of thin (1 to 20 cm) dredged material layers, map benthic disturbance gradients, and monitor the process of infaunal recolonization on, and adjacent to, the disposal mounds, and at reference areas. A detailed description of REMOTS® photograph acquisition, analysis, and interpretive rationale is given in DAMOS Contribution #60 (SAIC 1989).

A REMOTS® survey was conducted at the reference areas, at the inactive mounds (MQR, NHAV-74, CS-1, CLIS-89, FVP, and CLIS-88), and over the area of active disposal (CLIS-90 and CS-90-1). The reference areas were 2500 m west (2500W-REF), 4500 m east (4500E-REF), and 5094 m southeast (CLIS-REF) of the CLIS-87 buoy location (41°9.18′ N and 72°53.65′ W). The REMOTS® survey at each reference area consisted of a thirteen-station cross grid with stations 100 m apart. A thirteen-station cross grid was also used at the inactive disposal mounds (Figure 2-1). For the area of active disposal, a thirteen-station

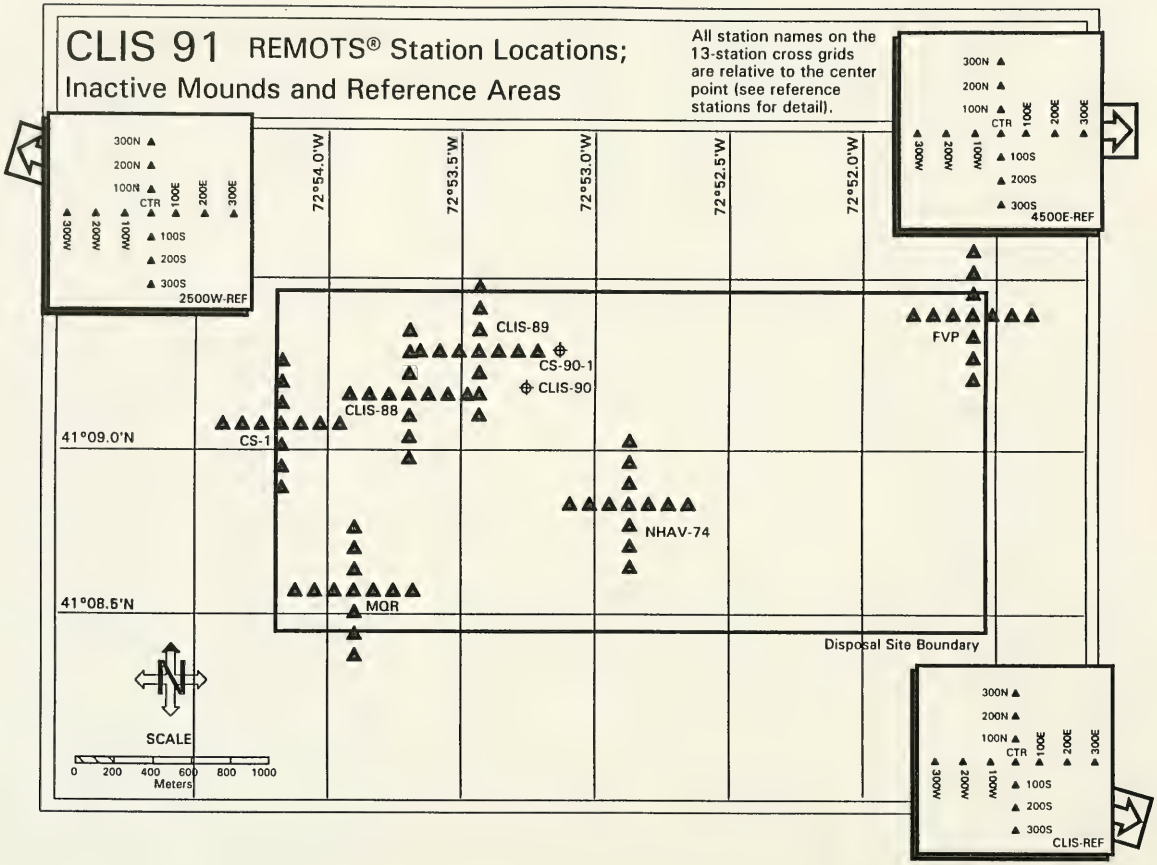


Figure 2-1. Locations and designations of REMOTS® stations over inactive mounds and reference areas surveyed at CLIS, June 1991

grid was centered over CS-90-1, and the sixty-six-station orthogonal grid that was used in 1990 was repeated in June 1991 (Figure 2-2). Three replicate photographs were taken at all REMOTS® stations.

2.3 Sediment Sampling and Analysis

Sediment samples were collected from the center of the reference areas (CLIS-REF, 4500E, and 2500W) with a 0.1 m^2 teflon-lined Van Veen grab sampler. Three samples were collected for analysis at each reference area with each sample originating from a separate grab. Subsamples from each grab were obtained using a 10 cm polycarbonate plastic core liner (6.5 cm ID). A composite of the cores (0-10 cm) provided sufficient sediment to fill precleaned 250 ml glass jars for chemical analyses (metals and PAHs). Sediments for grain size and total organic carbon (TOC) were placed in plastic bags. Samples were kept cold (approximately 4°C) and delivered to the NED laboratory. Triplicate samples for each reference area were analyzed for TOC, PAHs, cadmium (Cd), lead (Pb), and zinc (Zn). Grain size analyses were not run in triplicate, but on a composite sample for each reference area at the NED laboratory.

2.3.1 Grain Size Analysis

American Society for Testing and Materials (ASTM) Method D422 was used for grain size analysis (Table 2-1). Grain sizes were classified using the Wentworth classification (phi scale) of grain size that assigns gravel phi values between -2 and -1, sand between -1 and +4 inclusive, silts between 4 and 8 inclusive, and clays greater than 8. Before initiating the analysis, a subsample (approximately 5-20 gm) was taken to determine % total solids (% dry weight) and to allow for correction of percent moisture. Samples were separated by a sieve analysis into size fractions greater than 62.5 μm (<4 phi), sand and gravel, and less than or equal to 62.5 μm (≥ 4) silt and clay. Mechanically dry-sieving the sediment through a graded series of screens subdivided the gravel-sand fraction. The wet-sieved and dry-sieved fractions less than 62.5 μm were combined for each sample. A pipet technique that infers size by the settling rates of particles through a column of fresh water subdivided the silt-clay fraction.

2.3.2 Total Organic Carbon

Total organic carbon, a measurement of organic matter (both labile and refractory) in sediments, was measured using U.S. Environmental Protection Agency (EPA) Method 9060. The analyzer converted organic carbon in the samples to carbon dioxide (CO_2). An infrared detector measured the carbon dioxide. The amount of CO_2 is directly proportional to the concentration of carbonaceous material in the sample. Inorganic forms of carbon (carbonate and bicarbonate) are subtracted from the reported total organic carbon value.

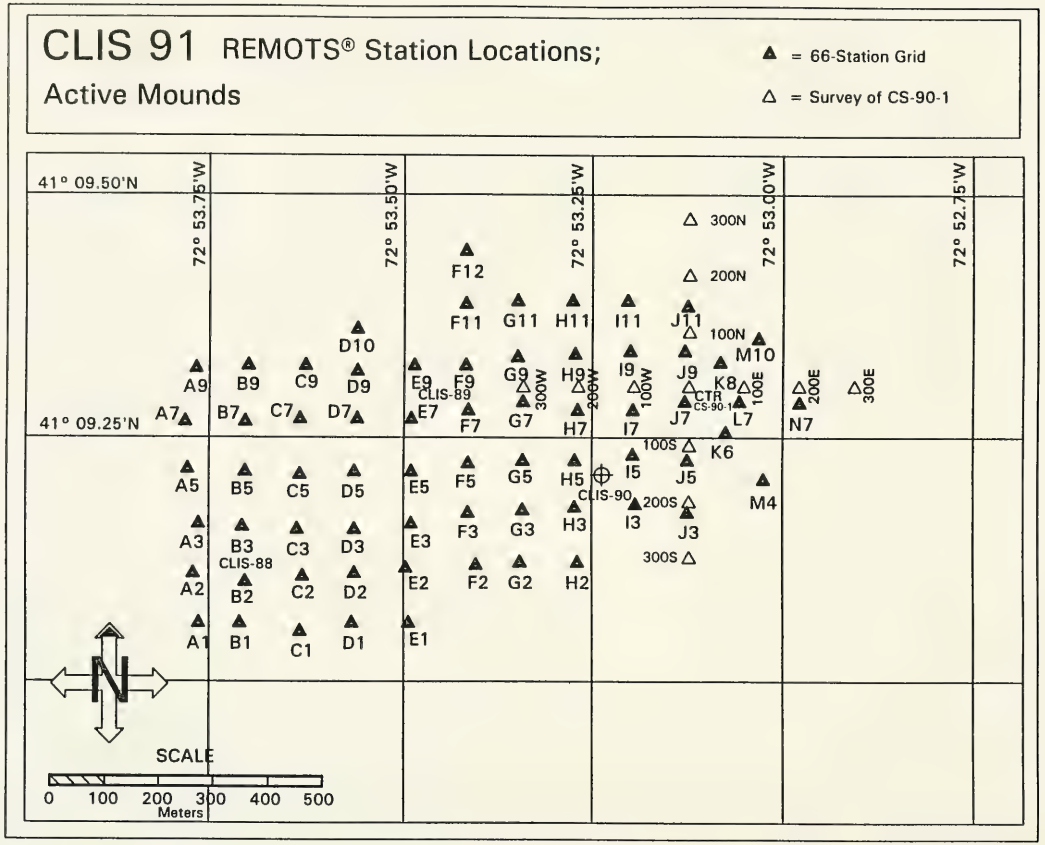


Figure 2-2. Locations and designations of REMOTS® stations over active disposal area, CLIS, June 1991

Table 2-1

Summary Of Laboratory Analytical Work, Summer 1991

TYPE OF TEST	TEST METHOD		INSTRUMENTATION
Metals	EPA Test Method No.		
	Sample Prep	Analytical	
Cadmium (Cd)	3050	7131	GFAA
Lead (Pb)	3050	7421	GFAA
Zinc (Zn)	3050	6010	ICP
Polynuclear Aromatic Hydrocarbons (PAHs)	3540	8270	GCMS
Total Organic Carbon		9060	
Grain Size	ASTM D422-63		

2.3.3 Metal and PAH Analyses

Samples were analyzed using standard EPA procedures (Table 2-1). Cadmium and lead were analyzed by graphite furnace atomic absorption techniques and zinc by inductively coupled argon plasma emission spectrophotometry (ICP). Atomic absorption techniques with a graphite furnace allow for low detection limits. The graphite furnace heats digestates in several stages, allowing removal of unwanted matrix components. Atomic absorption spectrophotometry determinations are completed as single element analyses. Analysis by ICP allows simultaneous or rapid sequential determination of many different metals. The detection limits associated with ICP analysis are frequently higher than those with atomic absorption spectrophotometry. Polynuclear aromatic hydrocarbons were analyzed by EPA Method 8270 which utilizes gas chromatography/mass spectrophotometry (GC/MS).

2.3.4 QA/QC

The NED laboratory submitted results that were acceptable and supported by appropriate documentation. The laboratory reported acceptable method detection limits, based on results obtained from the method blank processed with the samples. Several PAH

values were estimated because a particular compound was present in a concentration above the method detection limit, but below the practical quantitative limit. The practical quantification limit is the lowest level of measurement that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions for a sample of a particular matrix.

Quality control checks from the NED laboratory consisted of method blanks, matrix spikes, duplicate samples, and laboratory control samples. Method blanks are laboratory QC samples processed with the samples but containing only reagents. Method blanks test for contamination that the laboratory may have contributed during sample preparation. These method blanks were free of contaminants. Analysis of matrix spike samples provides a measure of the efficiency and effectiveness of sample preparation and analysis procedures. They also indicate how tightly a compound is bound to its matrix and whether or not interfering compounds are present. Matrix spikes are used to assess the accuracy of analytical measurements. Duplicate samples indicate variability in laboratory procedures and degrees of difference between individual samples. Duplicate blank spike and duplicate matrix spike samples were used to measure precision in laboratory procedures.

Laboratory control samples were standard reference materials analyzed using identical procedures as for the samples. Accuracy for the reference materials was within the control limits for the metals as well as the PAHs except for one value of fluoranthene. No other QC samples indicated laboratory problems with this compound, so no qualifiers were necessary.

2.4 CTD and Dissolved Oxygen Sampling

Speed of sound measurements were obtained prior to and following the bathymetric survey using a Seabird SEACAT SBE 19-01 CTD probe. The CTD was lowered over the side and allowed to equilibrate in ambient seawater for one to two minutes before initiating the cast. In addition, the CTD cast characterized depth gradients and assessed near-bottom DO concentrations relative to REMOTS® benthic analyses on and near the disposal site. The Seabird CTD collected salinity, temperature, and DO profiles at the center of the three reference areas (2500W, 4500E, and CLIS-REF) and at the center of the CLIS-90 disposal mound. Water samples from a Niskin cast approximately 1 m below the surface and 1 m above the bottom were sampled to measure near-surface and near-bottom DO values. A 300 ml subsample was drawn from the bottle, preserved, and titrated (duplicate aliquots of 50 mls) within twelve hours using a modification of the standard Winkler titration method (Strickland and Parsons 1972, Parsons et al. 1984). The intent of obtaining the titrated samples was to provide additional DO information should there be a problem with the CTD.

3.0 RESULTS

3.1 Bathymetry

The 1200 × 1200 m bathymetric survey conducted at CLIS in 1991 covered the area previously surveyed in July 1990 (Figure 3-1). After the July 1990 bathymetric survey, the disposal buoy was redeployed in September 1990 southeast of the CLIS-89 location (CLIS-90). The release of 59,000 m^3 of dredged material at the buoy formed a mound with a diameter of approximately 100 m and a minimum water depth of 16.6 m (Figure 3-2). The CS-90-1 capped mound was originally formed in the fall of 1989 and capped in the spring of 1990. It received an additional 8,730 m^3 of capping material during the 1990/1991 disposal season. In the 1991 bathymetric survey, the CS-90-1 mound had a diameter of 100 m and was at least 0.60 m in height (18.2 m minimum water depth) (Figure 3-2). Inactive mounds CLIS-88, CLIS-87, and CLIS-89 appeared to be unchanged between the 1990 and 1991 bathymetric surveys.

A visual comparison of the 1990 and 1991 surveys (Figures 3-1 and 3-2) shows a decrease in water depth from 18.8 m to 16.6 m at the CLIS-90 buoy location. At the CS-90-1 mound, minimum water depth increased from 18.0 m in 1990 to 18.2 m in 1991. The depth difference map comparing the two depth matrices indicated increased dredged material thickness of 2.4 m at the CLIS-90 mound and decreases of 0.2 m at CS-90-1 (Figure 3-3). The diameter of the CLIS-90 mound detected in the isopach map was approximately 200 m for thicknesses greater than 20 cm. Small deposits of material ≤ 40 cm were scattered to the west and south of this mound. Larger decreases in dredged material thickness on the southeast side of the CLIS-87/88 mounds may be a result of inaccuracies in comparing surveys conducted over a steeply sloping bottom. The seafloor in this area showed changes of up to 2 m over 25 m (Figure 3-4). A shift of approximately one boat width (10 m) in the lane navigation for compared surveys could result in apparent depth differences of 0.5 to 1.0 m. A volume calculation based on depth difference between the 1990 and 1991 survey indicated an increase of 39,503 m^3 of dredged material (95% confidence limits; 18,270 m^3 to 60,736 m^3).

3.2 REMOTS® Sediment-Profile Photography

3.2.1 Sediment Grain Size

3.2.1.1 Active Mounds

Within the main survey grid, there existed a patchy mosaic of silt-clay, very fine sand, fine sand, and medium sand (Figure 3-5). A large part of the surveyed area, particularly over the most recent disposal mounds, showed very fine or fine sand, reflecting the effects of disposal. The presence of silt-clay mud patches within this area apparently

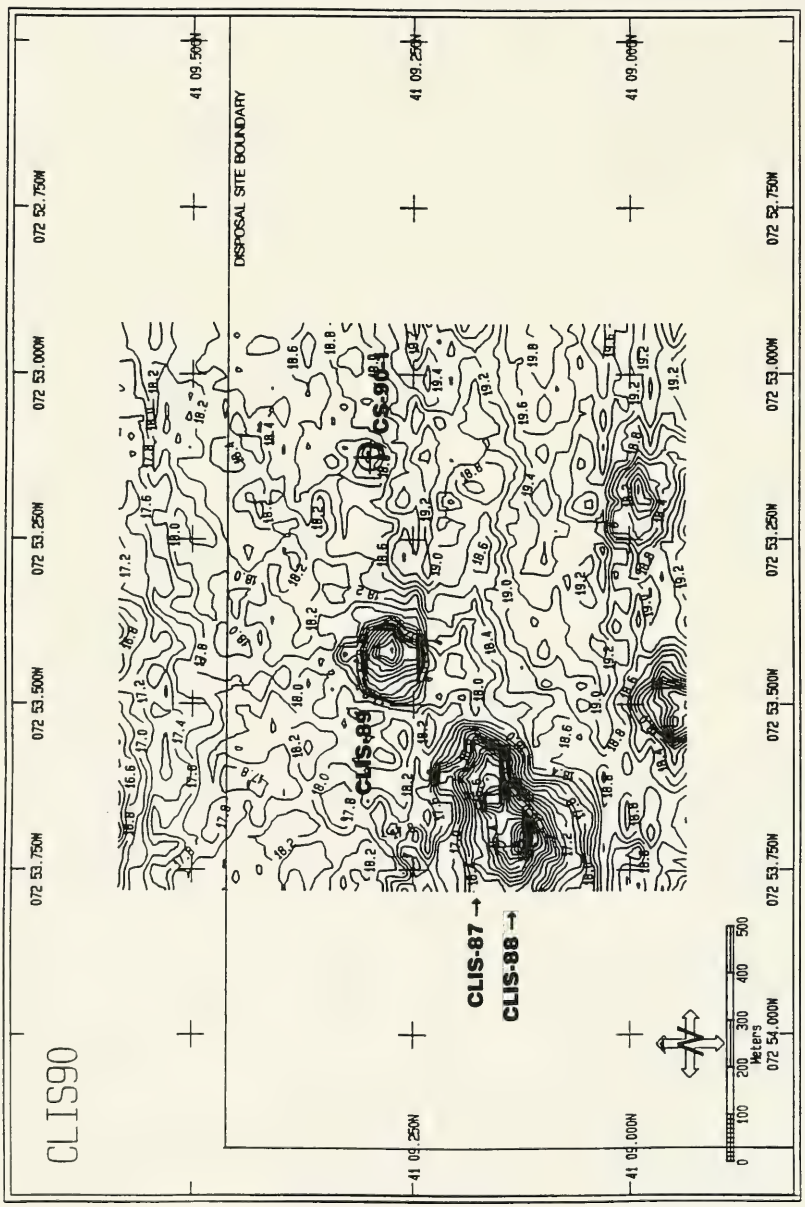


Figure 3-1. Contoured bathymetric chart (depth in meters) of CLIS, 17 and 18 July 1990

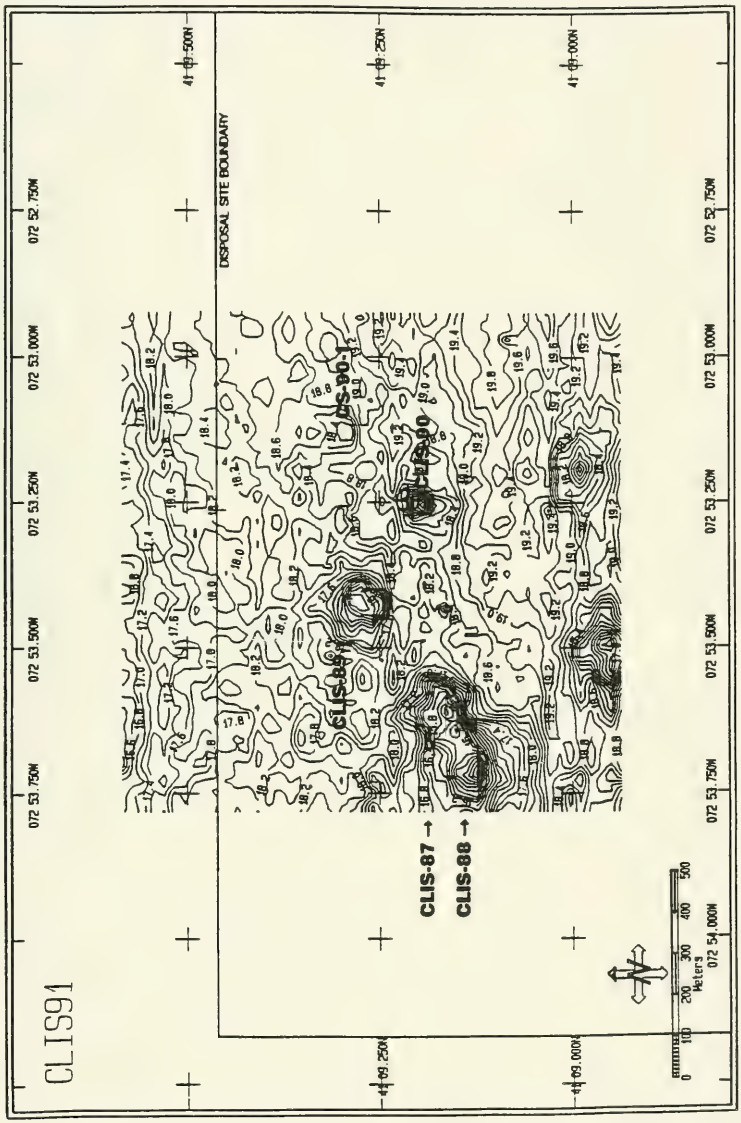


Figure 3-2. Contoured bathymetric chart (depth in meters) of CLIS, 21 June 1991

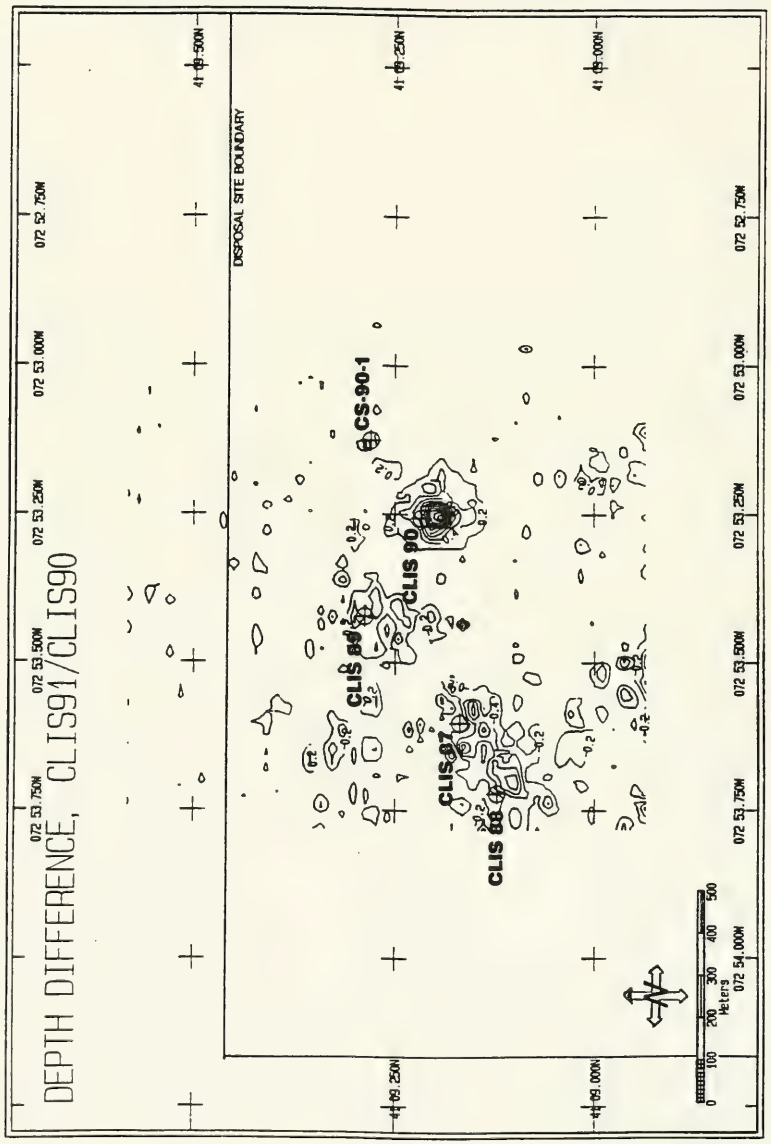


Figure 3-3. Contoured chart of changes in depth (meters) at CLIS from July 1990 to June 1991

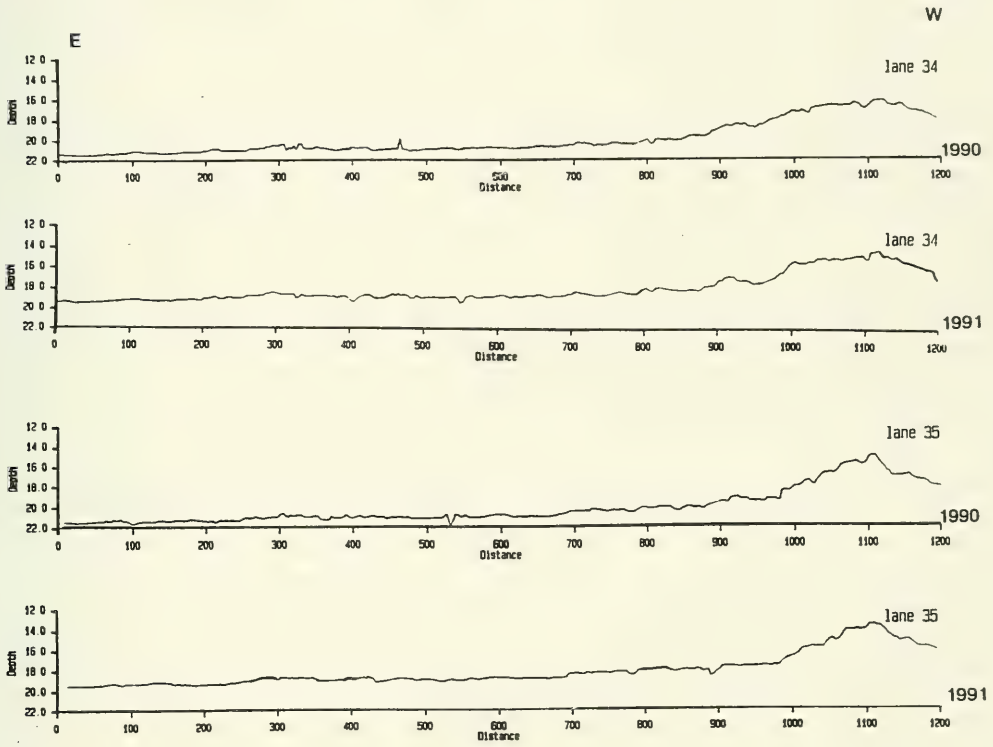


Figure 3-4. Profile plot of survey lanes 34 and 35, CLIS bathymetric surveys, 1990 and 1991

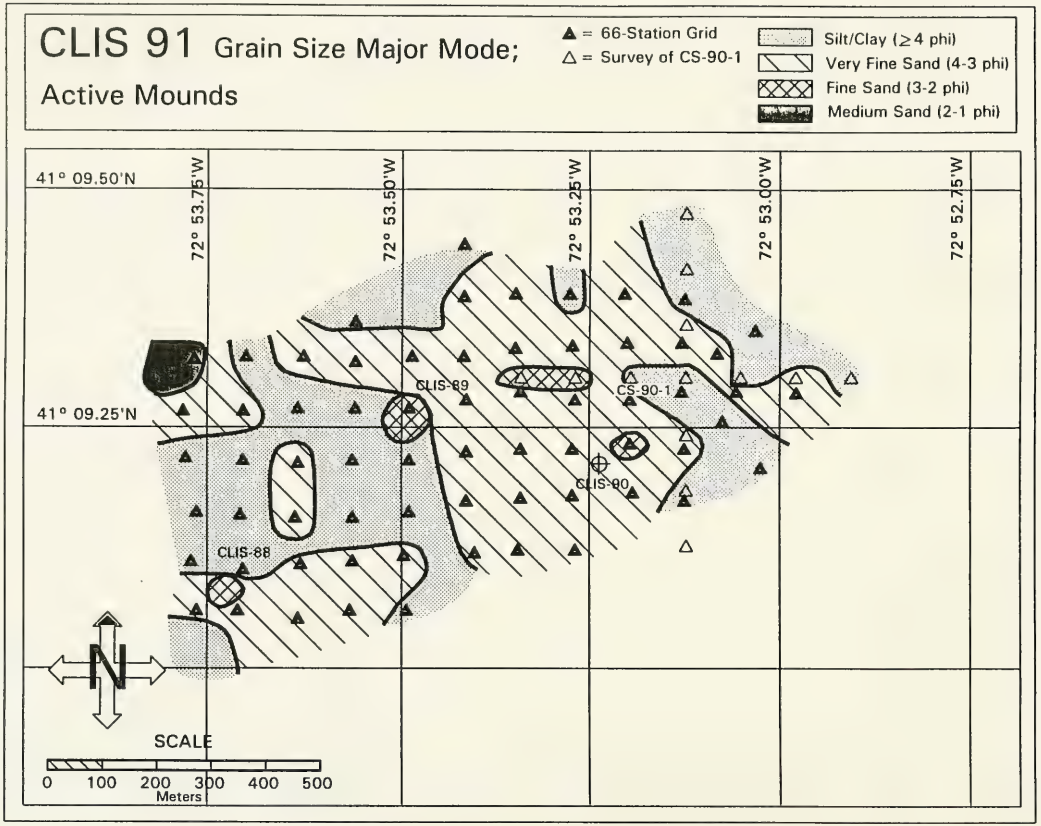


Figure 3-5. Map of sediment grain size major mode (in phi units) at CLIS active disposal mounds, June 1991

reflects both the presence of ambient bottom conditions (parts of the seafloor not yet covered with dredged material) and fine-grained mud that represents disposed materials. Grain size information from CLIS-88 and CLIS-89 surveys that overlaps the sixty-six-station grid has been incorporated into the distribution of grain size in the area (Figure 3-5).

3.2.1.2 Inactive Mounds and Reference Areas

The grain size major mode for inactive mounds CS-1, MQR, FVP, and NHAV-74 was mostly silt-clay (>4 phi). On mounds CLIS-88 and CLIS-89, the very fine sand and the fine sand, respectively, may be the result of extensive dredged material disposal in the area over time. The natural ambient bottom in the central Long Island Sound basin within and surrounding CLIS consists of brown to grey silt-clay mud (>4 phi) (Figure 3-6). Silt-clay was the dominant textural mode for CLIS-REF, 4500W-REF, and most of the 2500W-REF. Five stations at the 2500W-REF had a major textural mode in the 4-3 phi range. The water depth at this western reference area (13 m) is shallower than the CLIS-REF and the 4500E-REF areas. This very fine sand mode probably reflects the proximity of the western reference area to the mud-sand transition at approximately the 13 m depth contour in this part of the Sound (see NOAA Chart 12354).

3.2.2 Distribution of Dredged Material

3.2.2.1 Active Mounds

The CLIS-90 and CS-90-1 disposal locations at CLIS were in an area that received spatially dispersed dredged material over the past few years (Germano et al. 1993). All REMOTS® photographs in the CLIS survey area showed the presence of dredged material (Figure 3-7). Within the main survey area, the sediment is either fresh or relic dredged material based on sediment grain size, optical reflectance, and sediment fabric (SAIC 1990; Figure 3-8). The fresh dredged material followed a NE -SW trend through the center of the survey over the CLIS-90, CLIS-89, and part of the CS-90-1 mounds. Isolated patches of relic and fresh material occurred at one or two stations near the edge of the survey area.

3.2.2.2 Inactive Mounds and Reference Areas

The REMOTS® survey at the three reference areas detected only ambient sediment. Relic or more weathered dredged material was concentrated in the REMOTS® grids over inactive mounds CS-1, NHAV-74, and FVP. Station 100E at FVP was classified as fresh dredged material due to very dark reduced sediment at depth. At MQR, the REMOTS® photographs showed silt-clay dredged material with layered or chaotic fabrics, the presence of methane gas, and low reflectance of sediment below the RPD (resulting from high sulphide content). These are all characteristics often attributed to recent or fresh dredged material, but can also be indicative of retrograde conditions. Because there was no recent

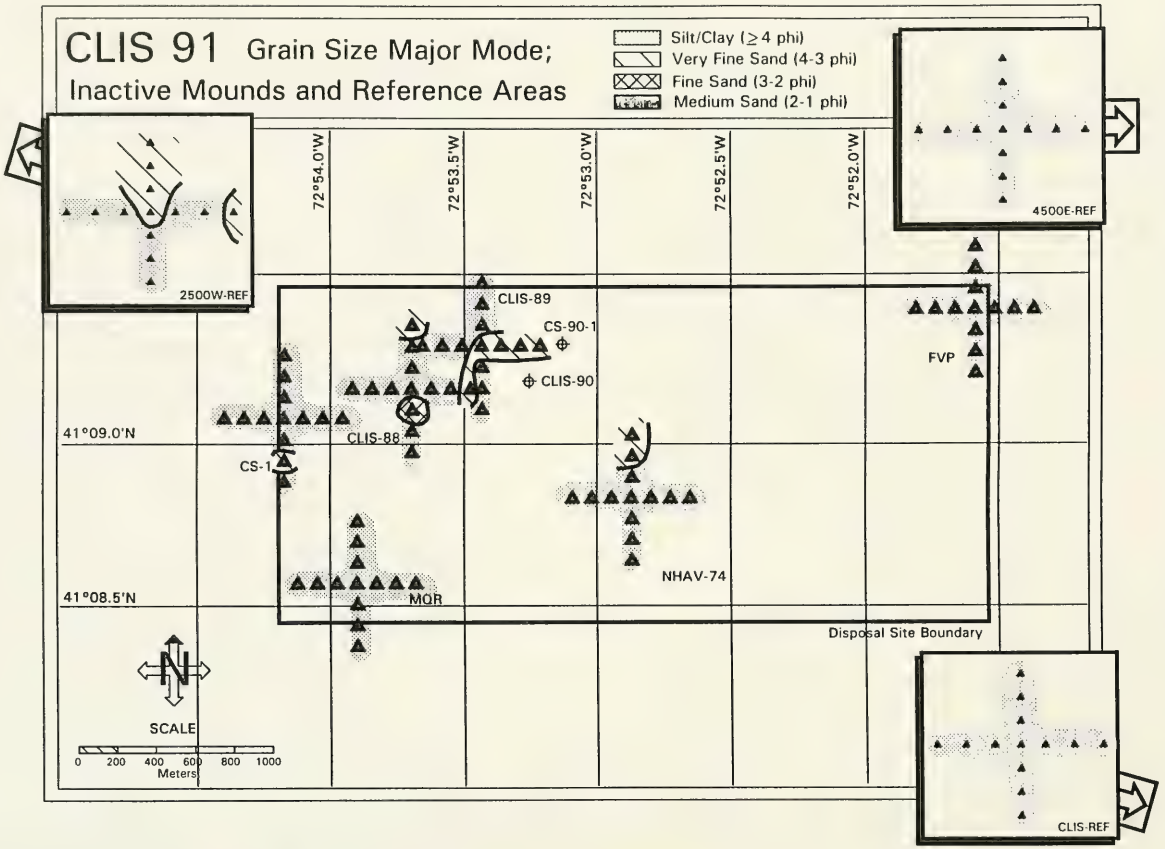


Figure 3-6. Map of sediment grain size major mode (in phi units) at CLIS inactive disposal mounds and reference areas, June 1991

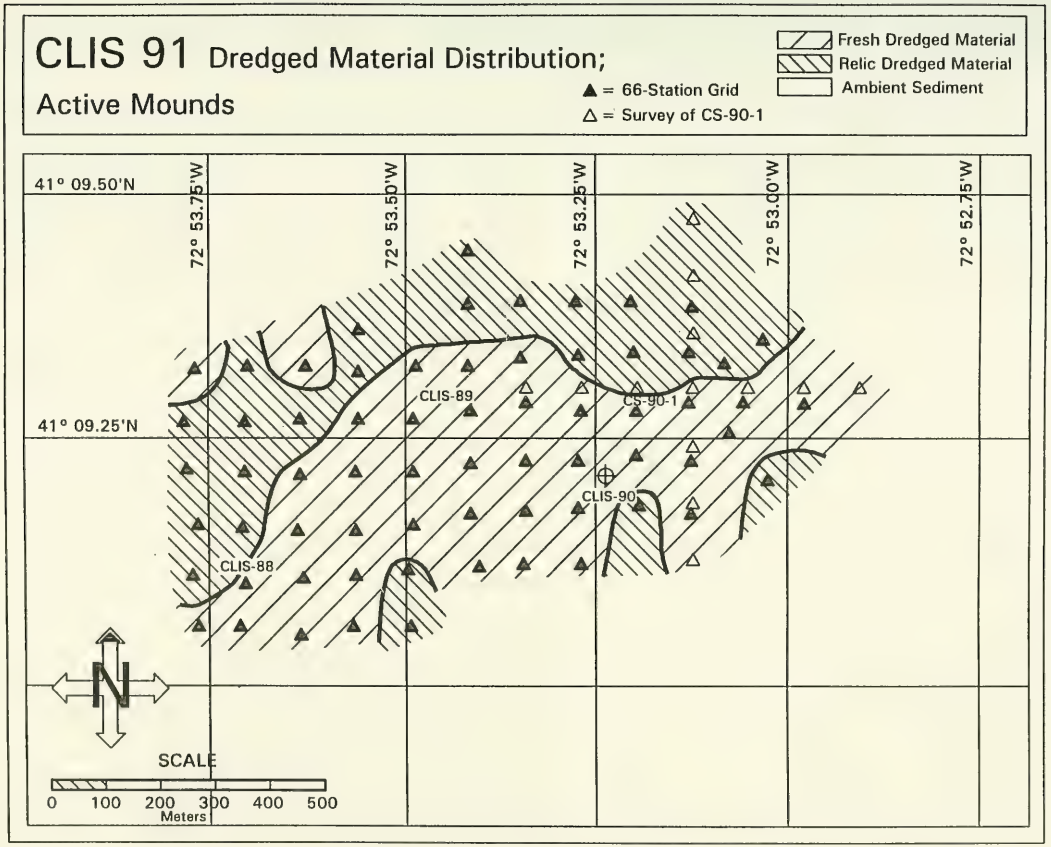
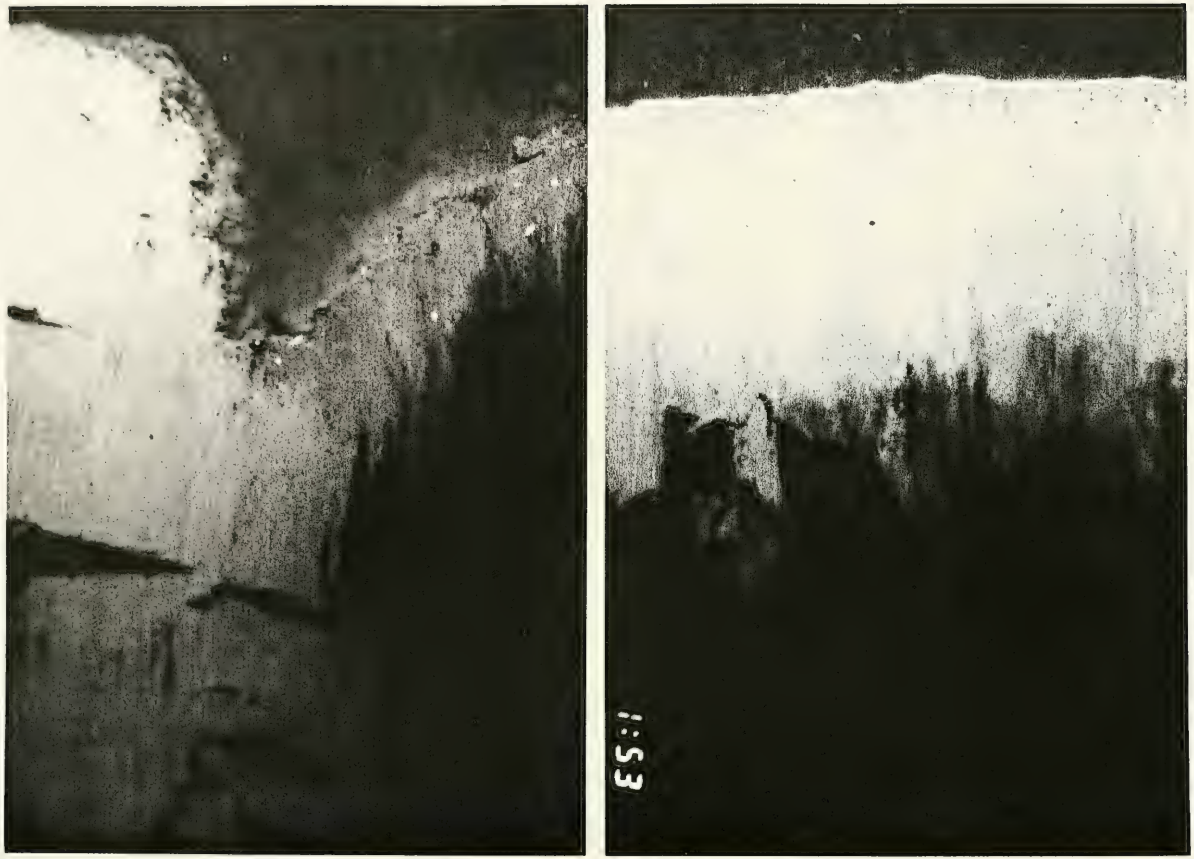


Figure 3-7. Distribution of dredged material at CLIS active disposal mounds, June 1991



M 10 NHAV-74 100E

Figure 3-8. REMOTS® photographs from stations M10 and NHAV-74 100E, showing "fresh" dredged material and relic dredged material, respectively

disposal at MQR, the apparent retrograde recolonization at MQR could be the a result of physical disturbance. It is also possible that these results indicate that the relic dredged material at these stations has inhibited extensive bioturbation activity (see Section 3.2.5.2). At CLIS-88 and CLIS-89, the stations closest to the active disposal locations display recent dredged material while the stations to the north and west contain relic dredged material (Figure 3-9).

3.2.3 Boundary Roughness

High boundary roughness produced by physical processes such as erosion or deposition of cohesive materials is typical of newly deposited dredged material. Old or relic dredged materials, particularly on the distal parts of mound flank deposits, have low boundary roughness due to "smoothing" by currents, small-scale bioturbation, and filling-in of relief from natural deposition (Figure 3-8).

3.2.3.1 Active Mounds

Over the main REMOTS® survey grid, boundary roughness values were low with most values being less than 3 cm. Only two stations had boundary roughness over 3.0 cm (I5 and M10). These stations were located (respectively) within 100 m of the CLIS-90 buoy and CS-90-1 mounds, and it is likely that this high relief is related to the recent deposition of dredged materials (Figure 3-10). Boundary roughness values at the disposal site stations were not significantly different from those at the reference areas (Figure 3-11; Mann-Whitney U-test, $p=.824174$).

3.2.3.2 Inactive Mounds and Reference Areas

All of the mean boundary roughness values at CS-1, CLIS-88, CLIS-89, FVP, and NHAV-74 were less than 3.0 cm. This indicates that remolding processes such as hydrodynamic "smoothing", deposition, and biological reworking have reduced the high relief associated with cohesive fresh dredged material at these inactive disposal mounds. At MQR, the boundary roughness value was 3.0 cm at 300W due to a sloping sediment water interface. Boundary roughness values at the three reference areas were all less than 2 cm (Figure 3-12).

3.2.4 Apparent RPD Depth

3.2.4.1 Active Mounds

In the disposal area grid, five stations had mean RPDs greater than 3 cm. Most stations had RPDs that fell within the class >1 cm and <3 cm. Where RPD depths were

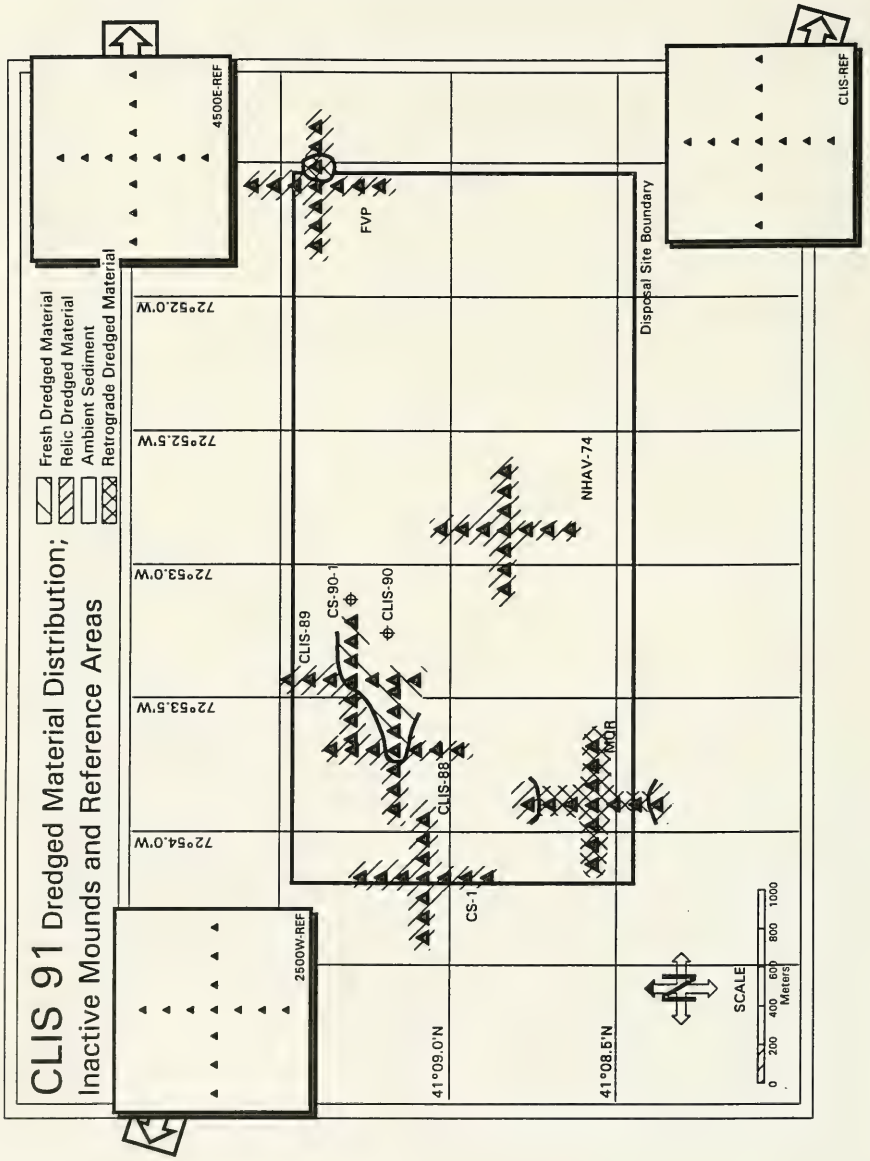


Figure 3-9. Distribution of dredged material at CLIS inactive mounds and reference areas, June 1991

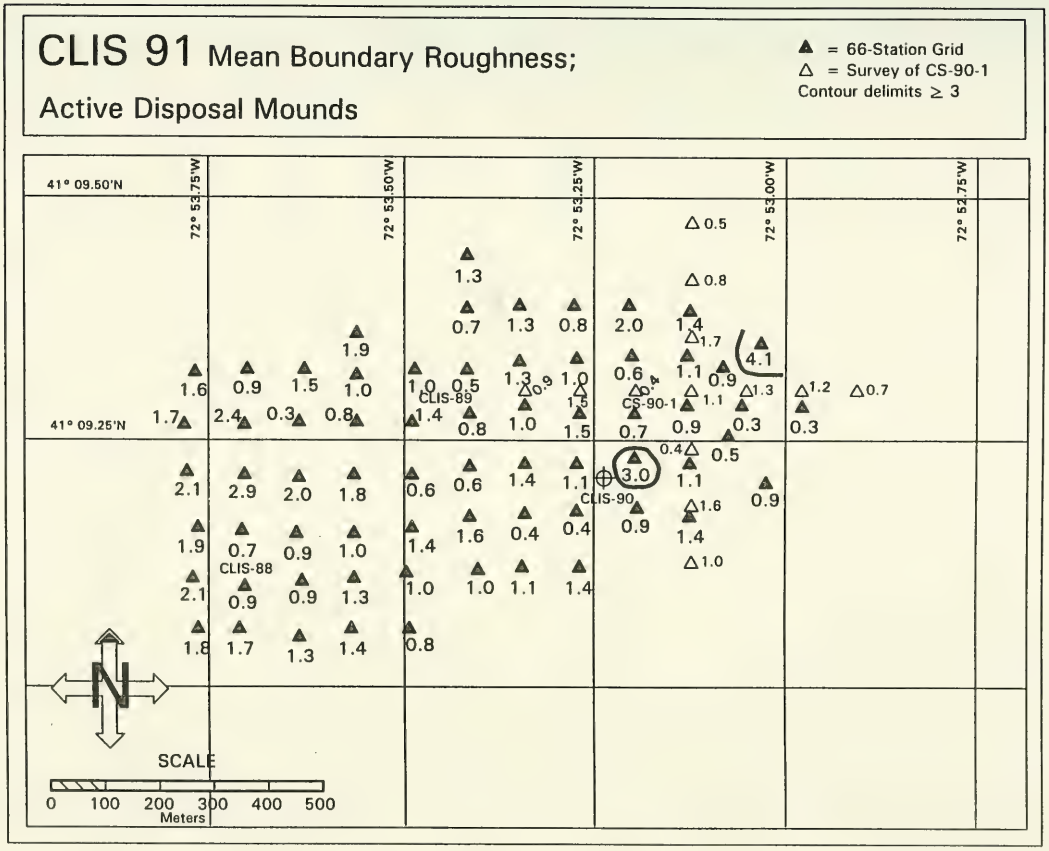


Figure 3-10. Map of mean small-scale surface boundary roughness values at CLIS active disposal mounds, June 1991

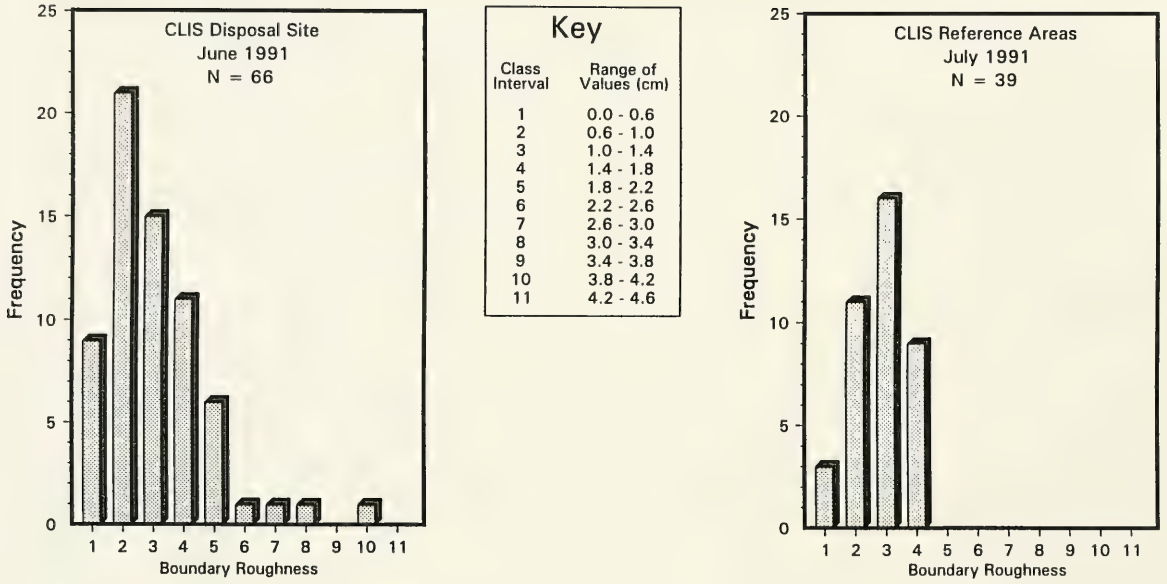


Figure 3-11. Frequency distribution of small-scale surface boundary roughness values at the disposal site and reference areas, June 1991

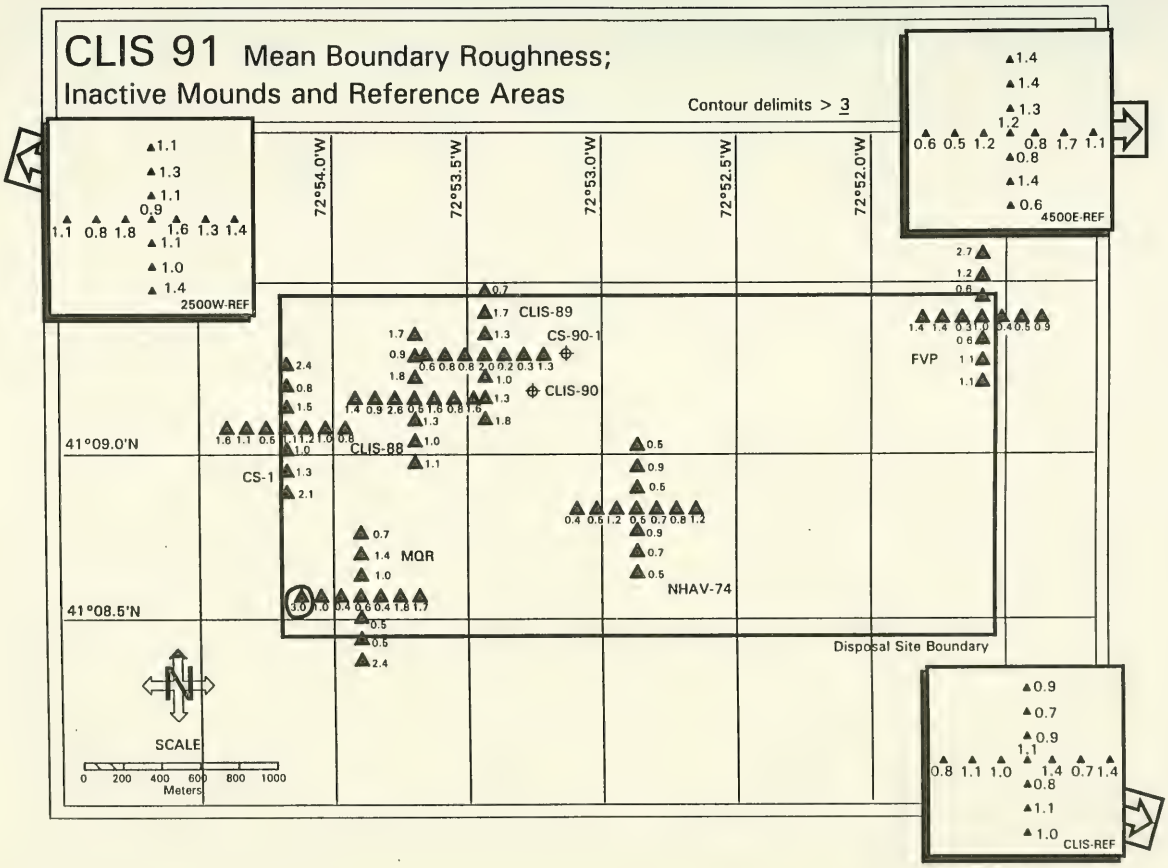


Figure 3-12. Map of mean small-scale surface boundary roughness values at CLIS inactive mounds and reference areas, June 1991

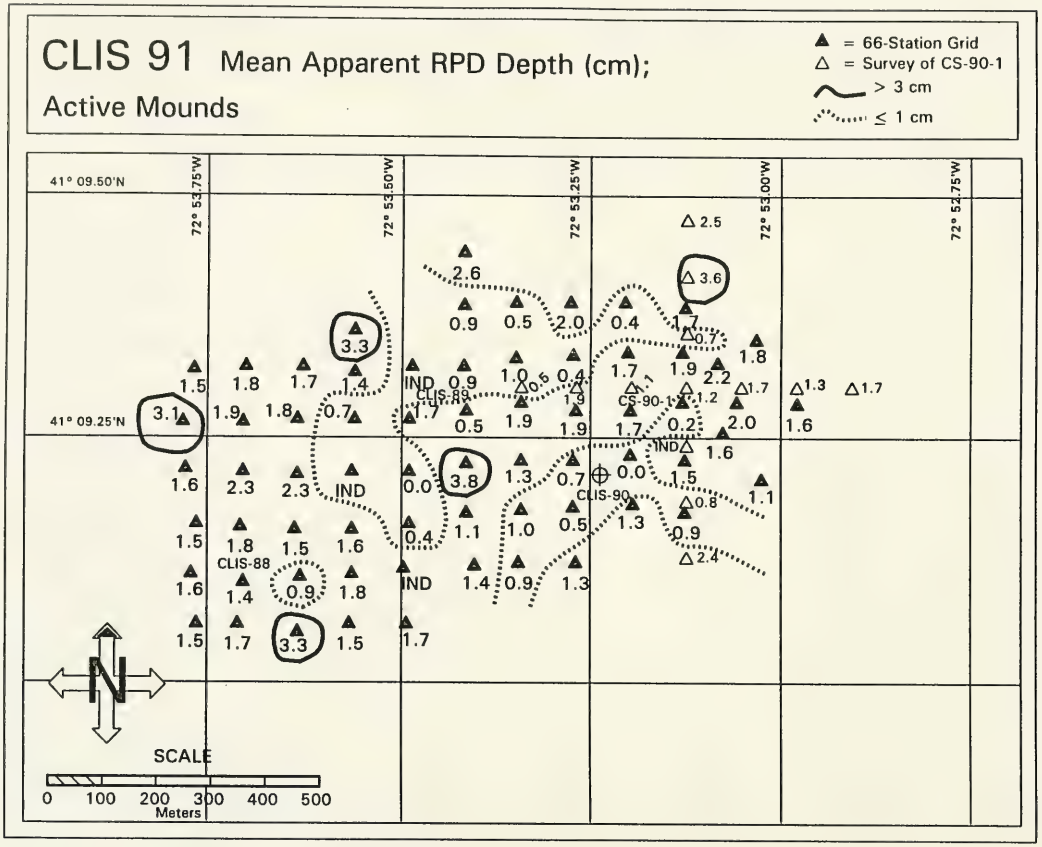


Figure 3-13. The mapped distribution of apparent RPD depths (cm) at CLIS active disposal mounds, June 1991

≤ 1 cm deep, the stations cluster together, aligning in a NE-SW orientation over CLIS-90 and north of CS-90-1 (Figure 3-13). Based on the original sixty-six-station grid over the active mounds, and the reference areas, the RPD values were significantly different between the disposal site and the reference areas (Figure 3-14; Mann-Whitney U-test, $p < 0.001$).

3.2.4.2 Inactive Mounds and Reference Areas

All three reference areas had mean apparent RPD depths greater than 1 cm. Nineteen out of thirty-nine stations had RPD depths greater than 3 cm (Figure 3-15). Inactive mounds FVP and NHAV-74 had RPD values similar to 2500W-REF and 4500E-REF. At MQR, eight stations located near the center of the MQR mound apex (100E, 100N, 100S, 100W, 200E, 200N, 200W, and CTR) had mean apparent RPD depths that were anomalously shallow relative to the three reference areas. Inactive mounds CS-1, CLIS-88, and CLIS-89 had one station with RPD depth less than or equal to 1 cm, eight stations greater than 3 cm, and thirty stations between 1 and 3 cm.

3.2.5 Successional Stages

3.2.5.1 Active Mounds

Within the survey area, the only apparent successional stage pattern involving several stations was the NE-SW orientation over CS-90-1 and CLIS-90, and stations clustered on the eastern side of the survey, with only Stage I taxa (Figure 3-16). Isolated areas of azoic (station E5), Stage I, and Stage II organisms occurred where dredged material was deposited within the last two years (Germano et al. 1993).

3.2.5.2 Inactive Mounds and Reference Areas

All stations within the three CLIS reference areas contained Stage III infauna except for 100W at the 2500W-REF area (Figure 3-17). On the inactive mounds, Stage III fauna predominated. Only Stage I fauna was present at CS-1 300E, and MQR 200N, 200S, and 200E.

3.2.6 Organism-Sediment Index

The multiparameter REMOTS® Organism-Sediment Index (OSI) characterizes habitat disturbance. The parameters used to calculate the OSI values are the mean apparent RPD depth, the presence of methane or the inferred absence of dissolved oxygen in surface sediment pore waters, and the successional stage (SAIC 1989). Based on the results of past REMOTS® surveys, OSI values ≤ +6 indicate a recently or chronically stressed benthic habitat (e.g., erosion, dredged material disposal, hypoxia, demersal foraging, etc.; Rhoads and Germano 1986).

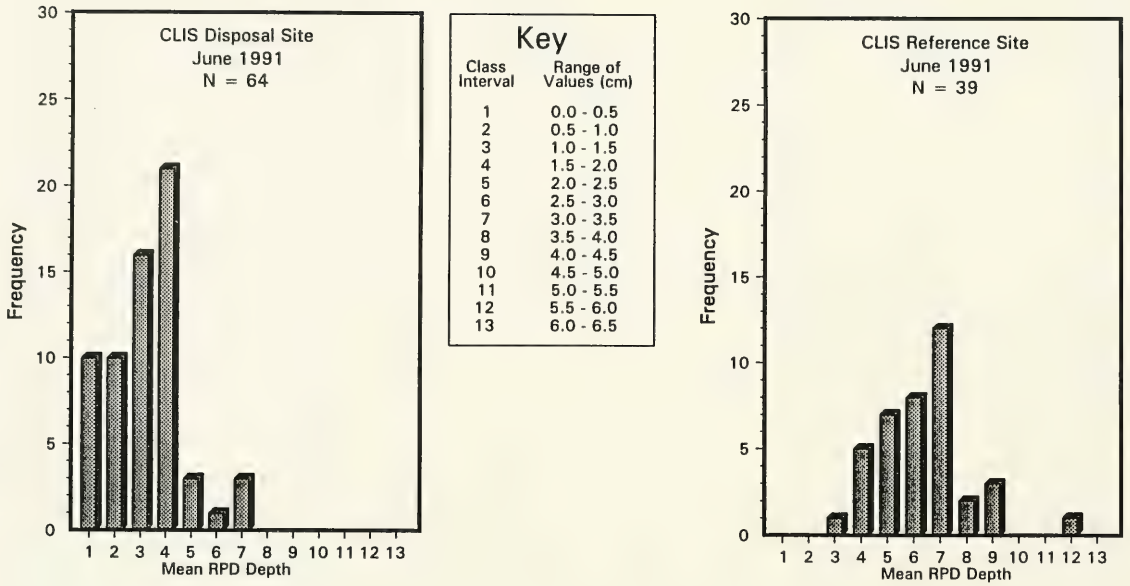


Figure 3-14. Frequency distribution of apparent RPD depths for all reference areas and disposal site stations at CLIS, June 1991

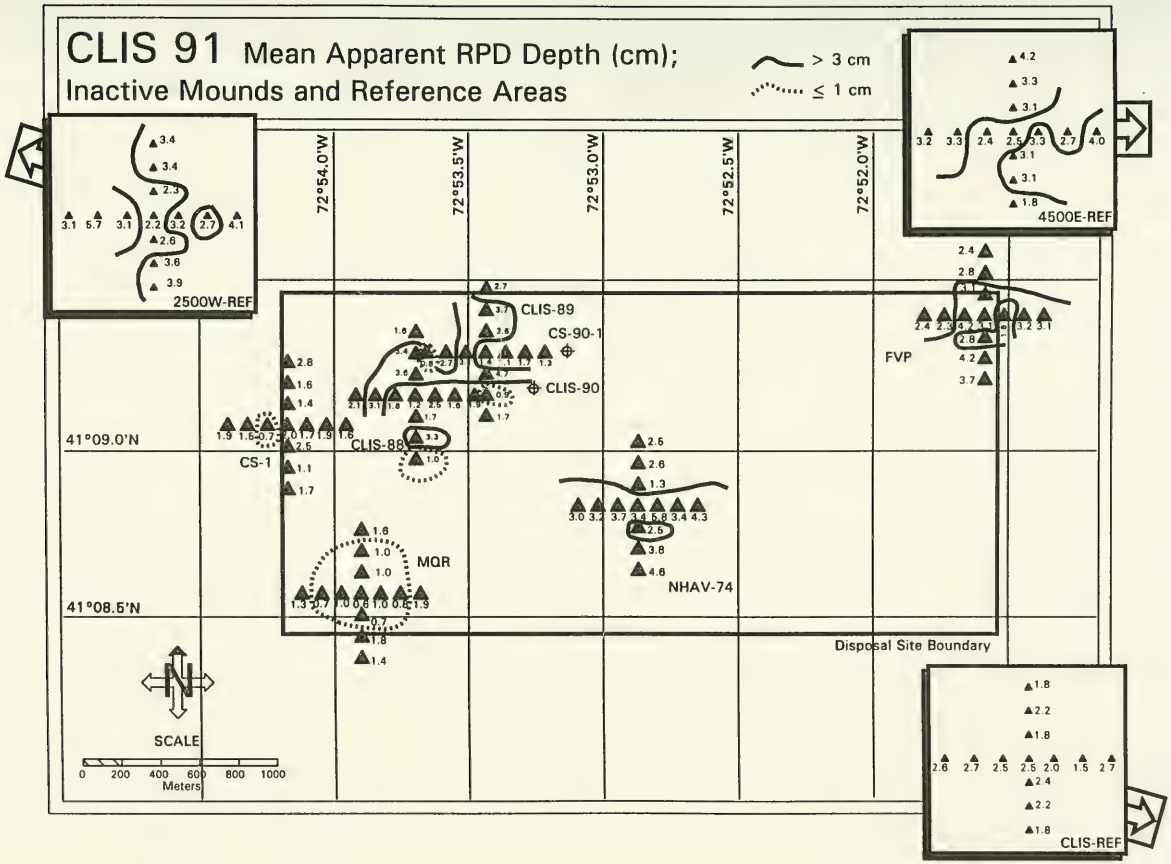


Figure 3-15. The mapped distribution of apparent RPD depths (cm) at CLIS inactive disposal mounds and reference areas, June 1991

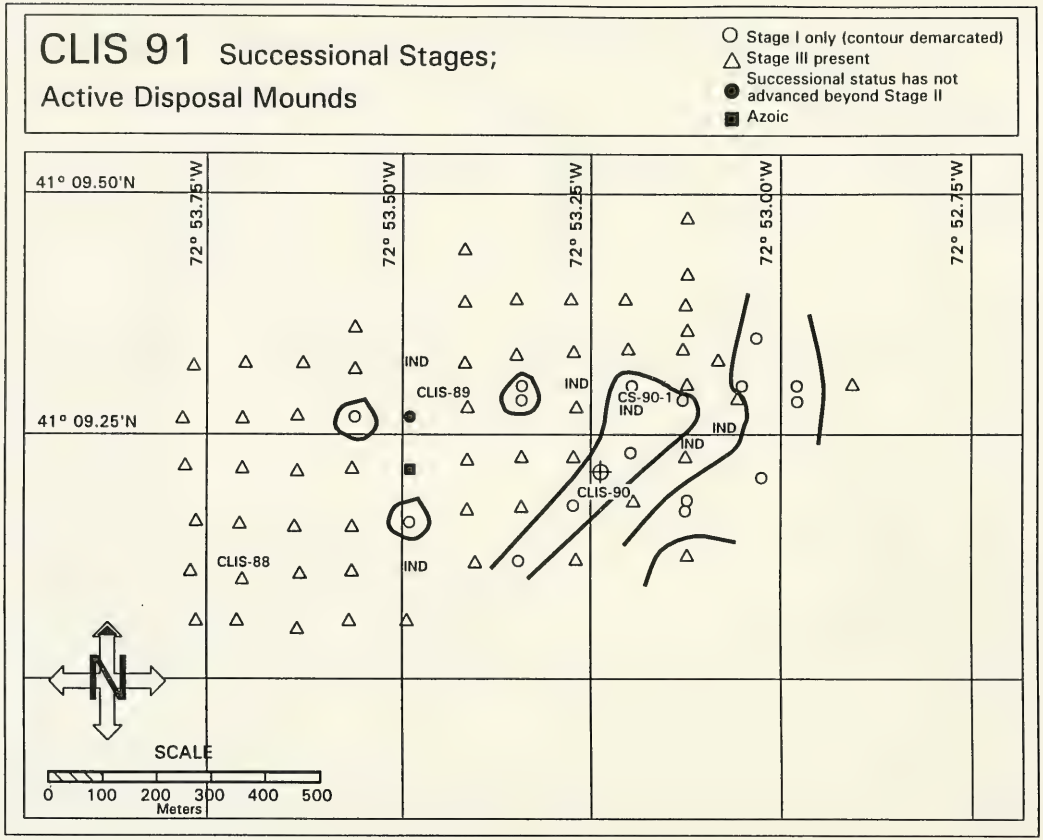


Figure 3-16. The mapped distribution of infaunal successional stages at CLIS active disposal mounds, June 1991

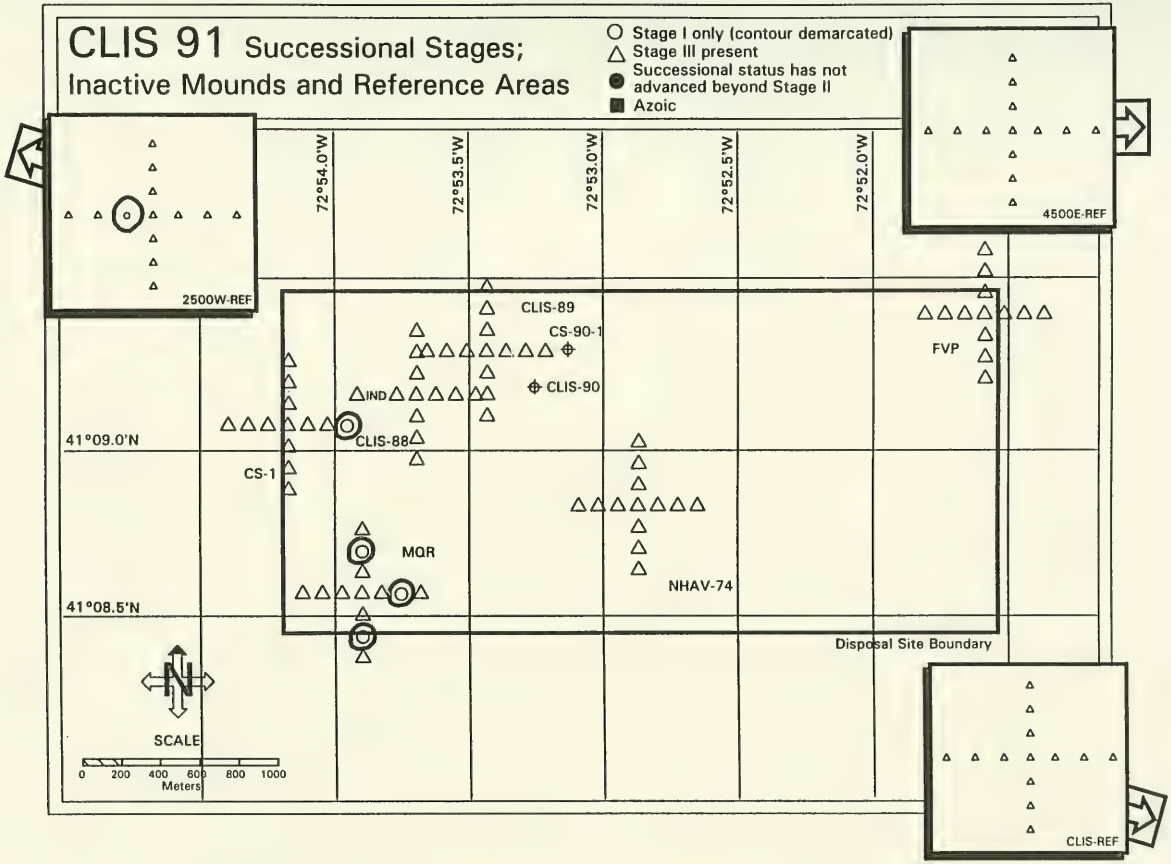


Figure 3-17. The mapped distribution of infaunal successional stages at CLIS inactive disposal mounds and reference areas, June 1991

3.2.6.1 Active Mounds

Within the CLIS survey area, median OSI values ranged from 0.5 to 10. Lower values predominate in the area of the two active mounds, CLIS-90 and CS-90-1 (Figure 3-18). OSI values were also less than +6 south of CLIS-89 and in the northwest area of the survey. Where the median OSI value is +0.5, (southwest of CLIS-89) there appeared to have been recent trawling or other physical disturbance. Between the original sixty-six-station grid over the active mounds, and the reference areas, the OSI values were significantly different (Figure 3-19; Mann-Whitney U-test, $p < 0.001$).

3.2.6.2 Inactive Mounds and Reference Areas

On the inactive mounds, FVP, MQR, and NHAV74, the OSI values were not significantly different from the main REMOTS® survey area (Mann-Whitney U-test, $p=0.374$, 0.512, and 0.513, respectively). At NHAV-74 and FVP, the OSI values were greater than +6 for most stations. On the MQR mound, most OSI values fell between +1 and +3 cm. On CLIS-88 and CLIS-89, OSI values ranged from 4 to 11. The median OSI values for the three reference areas were predominantly greater than OSI = +6 (Figure 3-20).

3.3 Sediment Analysis

3.3.1 Grain Size and Total Organic Carbon

Grain size analyses were conducted on samples retrieved from the center of 2500W-REF, 4500E-REF, and CLIS-REF (Table 3-1). All samples were dark grey clay-silt with shell fragments. The percentage of sand versus silt/clay was similar for all the reference areas. Of the silt/clay fraction, silt dominated at all three areas. Grain size results were 87% silt/clay and 13% sand for 2500W-REF and CLIS-REF. The sample from 4500E-REF was 12% sand and 88% silt/clay. These results corresponded with the grain size major mode determined by REMOTS® for 4500E-REF and CLIS-REF. The REMOTS® grain size determination at the center of 2500E-REF, very fine sand (4-3 phi), was coarser than the silt/clay determined by grain size analysis. REMOTS® stations 100 m away from the center were consistent with the laboratory grain size analysis. The average percent TOC was highest at 2500W-REF (1.05%), followed by 0.89% at CLIS-REF, and 0.83% at 4500E-REF.

3.3.2 Metals

Cadmium (Cd), lead (Pb), and zinc (Zn) were detected at all three reference areas. Values for cadmium ranged from 0.15 to 0.28 ppm; lead 51 to 76 ppm; and zinc 130 to 210 ppm. Replicate values were within approximately one standard deviation of the mean (Table 3-2). The average values for Cd, Pb, and Zn were slightly higher at 2500W than at

the other reference areas. CLIS-REF and 4500E showed similar average values for Cd, Pb, and Zn.

Table 3-1

Results of Sediment Grain Size Analyses and Percent Total Organic Carbon (TOC) for CLIS Reference Areas, June 1991

	2500W	4500S	CLIS-REF
DESCRIPTION	**Dark grey clay-silt with shell fragments**	**Dark grey clay-silt with shell fragments**	**Dark grey clay-silt with shell fragments**
% TOTAL ORGANIC CARBON			
Rep 1	1.15	0.92	0.87
Rep 2	0.97	0.71	0.88
Rep 3	1.04	0.86	0.92
Average	1.05	0.83	0.89
GRAIN SIZE ANALYSIS			
% Coarse Sand (1 to -1 phi)	2	2	2
% Medium Sand (2 to 1 phi)	5	4	4
% Fine Sand (4 to 2 phi)	6	6	7
% Silt (≥4 phi)	51	59	57
% Clay (≥4 phi)	36	29	30

Table 3-2

Metals Results (ppm Dry Weight) for Sediments Collected at the CLIS Reference Areas, June 1991

Metals (ppm dry weight)	Cd	Pb	Zn
2500W			
Rep1	0.25	76	210
Rep2	0.28	71	170
Rep3	0.23	61	150
Average	0.25	69	177
1SD	0.02	6	25
4500E			
Rep1	0.20	59	140
Rep2	0.21	58	140
Rep3	0.17	51	150
Average	0.19	56	143
1SD	0.02	4	5
CLIS-REF			
Rep1	0.24	62	130
Rep2	0.15	61	130
Rep3	0.16	58	140
Average	0.16	60	133
1SD	0.04	2	5
Method Detection Limit	0.05	0.30	0.50

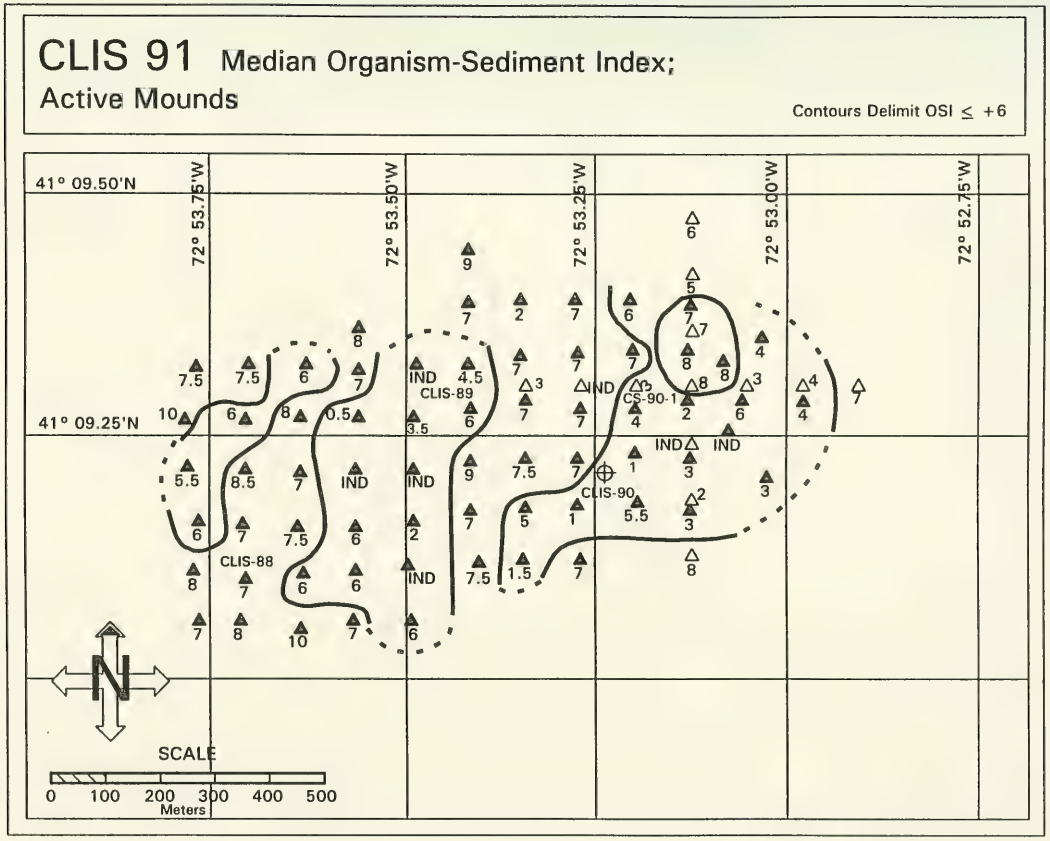


Figure 3-18. The distribution of median Organism-Sediment Indices at CLIS active mounds, June 1991

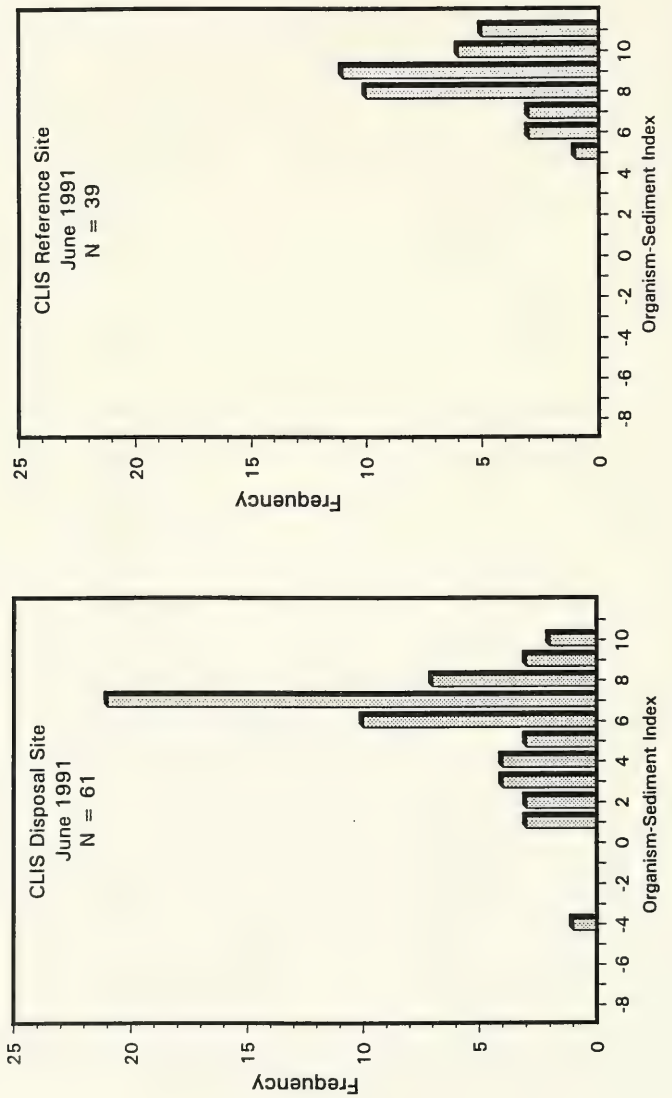


Figure 3-19. Frequency distribution of Organism-Sediment Indices for all the reference area and disposal site stations at CLIS, June 1991

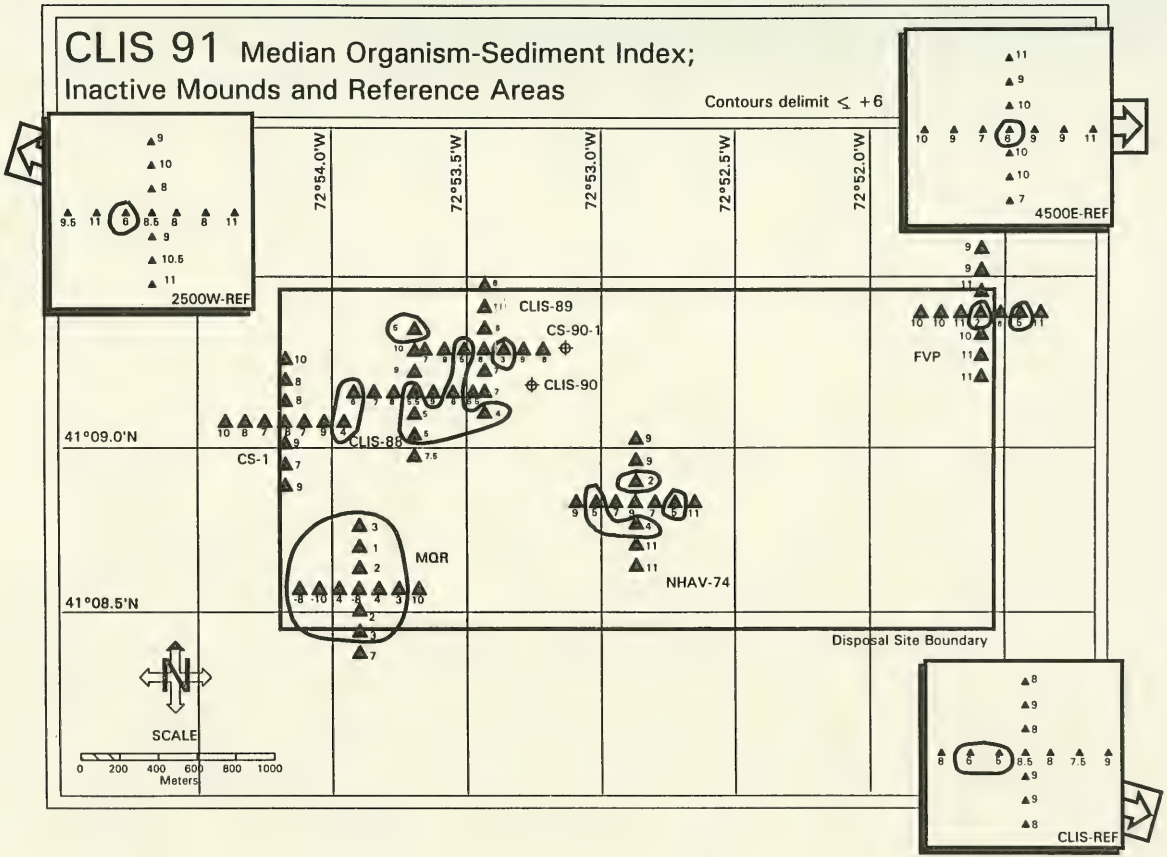


Figure 3-20. Distribution of median Organism-Sediment Indices at CLIS reference stations and inactive mounds

3.3.3 PAHs

Replicate PAHs at each reference area were more variable than results for the metal analyses; values fell within two standard deviations of the mean (Table 3-3). Several values were qualified as estimated (J values) indicating that a compound was present in a concentration above the method detection limit and below the practical quantitation limit. Of the low molecular weight (LMW) PAHs, phenanthrene was the most abundant at all three reference areas with average values of 167 ppb at CLIS-REF, 173 ppb at 4500E, and 247 ppb at 2500W. The average value of naphthalene, 127 ppb, was also higher at 2500W in comparison to the other two reference areas. Fluorene, acenaphthene, and acenaphthylene were below detection limit at CLIS-REF and either found in low concentrations or below detection limit at 4500E and 2500W reference areas. Total LMW PAH values were highest at 2500W and lowest at CLIS-REF.

High molecular weight (HMW) PAHs were detected at all the reference areas, except for dibenzo(a,h)anthracene, which was below detection limits at all the reference areas, and indeno(1,2,3-cd)pyrene, which was below detection limits at 4500E and CLIS-REF. Concentrations were greatest for pyrene with average values of 373 ppb at CLIS-REF, 410 ppb at 4500E, and 607 ppb at 2500W. Fluoranthene was also detected in higher concentrations relative to the other HMW PAH compounds: 257 ppb at CLIS-REF, 287 ppb at 4500E, and 423 ppb at 2500W. Total values for HMW PAH compounds were greatest at reference area 2500W, followed by 4500E and CLIS-REF.

3.4 CTD and Dissolved Oxygen Sampling

All water column measurements were made on June 18 to facilitate comparisons between sampling stations. The water column overlying the three reference areas and CLIS-90 buoy location had similar temperature-salinity structure with a strong midwater pycnocline from 1 m (2500W-REF) to 12 meters (CLIS-REF) (see Appendix). Below the pycnocline, temperature and salinity remained constant to the bottom (total depth at 2500W = 13 m, 4500E = 20 m, CLIS-REF = 17 m, CLIS-90 = 18 m). The 2500W REF station had a 1.5 m thick isothermal surface layer 1°C higher in temperature than the other areas. Temperature and salinity were constant below 11 m.

Dissolved oxygen profiles at 4500E-REF, CLIS-REF, 2500W-REF, and the CLIS-90 mound decreased from the surface to the bottom water. Dissolved oxygen below the pycnocline was lower than concentrations above the pycnocline by 2 to 3 ppm. The concentration of DO in bottom water ranged from 6 to 7 ppm at all stations (Table 3-4).

Table 3-3

Results of PAH Analyses (ppb Dry Weight) for Sediments
collected at the CLIS Reference Area, 1991

REFERENCE AREAS	2500W					4500E					CLIS-REF					
PAHs (ppb) dry weight	Rep1	Rep2	Rep3	Mean	1 SD	Rep1	Rep2	Rep3	Mean	1 SD	Rep1	Rep2	Rep3	Mean	1 SD	Method Detection Limit
Low Molecular Weight																
naphthalene	J 110	J 130	140	127	12	J 49	J 69	J 68	62	9	J 48	J 26	J 46	40	10	<6.7
2-methyl naphthalene	J 38	J 44	J 43	42	3	J 25	J 27	J 27	26	1	J 16	J 13	J 15	15	1	<6.7
acenaphthylene	< 19	J 29	< 14	21	6	J 25	J 27	< 14	22	6	< 16	< 13	<15	15	1	<6.7
acenaphthene	< 19	J 15	< 14	16	2	< 12	< 14	< 14	13	1	< 16	< 13	<15	15	1	<6.7
fluorene	< 19	J 29	J 29	26	5	J 25	< 14	< 14	18	5	< 16	< 13	<15	15	1	<6.7
phenanthrene	250	230	260	247	12	150	190	180	173	17	180	170	150	167	12	<9.8
anthracene	J 57	J 58	J 86	67	13	J 25	J 55	J 54	45	14	J 48	J 26	J 30	35	10	<6.7
TOTAL				546					359					302		
High Molecular Weight																
fluoranthene	470	390	410	423	34	270	330	260	287	31	290	240	240	257	24	<6.7
pyrene	610	600	610	607	5	360	480	390	410	51	430	320	370	373	45	<6.7
benzo(a)anthracene	230	200	240	223	17	160	210	160	177	24	190	140	J140	157	24	<6.7
chrysene	270	250	260	260	8	170	250	180	200	36	220	160	180	187	25	<6.7
benzo(b)fluoranthene	270	230	290	263	25	190	260	150	200	45	220	180	180	193	19	<6.7
benzo(k)fluoranthene	270	230	290	263	25	190	260	150	200	45	220	180	180	193	19	<6.7
benzo(a)pyrene	230	220	230	227	5	170	180	190	180	8	180	170	170	173	5	<6.7
dibenzo(a,h)anthracene	< 19	< 15	< 14	16	2	< 12	< 14	< 14	13	1	< 16	< 13	< 15	15	1	<6.7
benzo(g,h,i)perylene	230	230	230	230	0	170	210	190	190	16	J130	J110	170	137	25	<6.7
indeno(1,2,3-cd)pyrene	380	< 15	< 14	136	172	< 12	< 14	< 14	13	1	< 16	< 13	< 15	15	1	<6.7
TOTAL				2648					1870					1700		

1SD: 1 Standard Deviation from the mean; detection limit used in calculations for data below detection (<).
J = Estimated value; greater than detection limit, but less than practical quantitation limit.

Table 3-4

Dissolved Oxygen Concentrations at Selected Disposal Site
and Reference Stations at CLIS, June 1991
(Concentrations are in $mg \cdot l^{-1}$)

Station	At Bottom
CLIS-REF	6.77
4500E	6.60
2500W	6.30
CLIS-90	6.50

4.0 DISCUSSION

The following discussion addresses the four major objectives of the 1991 DAMOS CLIS survey: to define the topography and footprint of the active disposal mounds, to evaluate the successional status of active and inactive disposal mounds, to collect sediment chemistry information at the three reference areas, and to determine the potential role of bottom water dissolved oxygen as an ecological variable.

4.1 Disposal Mound Topography

The objective of the combined REMOTS® and precision bathymetric surveys was to delineate the extent and topography of the deposit resulting from dredged material disposal at CLIS since the 1990 survey. At the CS-90-1 buoy location, material released in 1989 had been capped since 1990. The CLIS 1991 survey was also designed to detect any of the material released at CS-90-1 since 1989. The bathymetric survey showed a significant accumulation of dredged material near the CLIS-90 disposal buoy and smaller amounts at the CS-90-1 buoy. However, the radius of the CLIS-90 disposal mound detected by the bathymetric survey (>20 cm thick above ambient bottom) was 100 m rather than the predicted 200 to 250 m (Figure 3-3). Based on the detection of dredged material by REMOTS® ($\leq$ 20 cm), "fresh" and relic dredged material is present over the whole survey area. "Fresh" dredged material extends more than 100 m south of CS-90-1 and north and west of CLIS-90.

The distinction made between "fresh" or recent dredged material, and relic or older dredged material, is based on a "fresh" signature exhibiting thin or patchy RPDs (redox potential discontinuities), physical layering or chaotic sedimentary fabric near the surface due to a lack of bioturbation, and high boundary roughness. The "fresh" appearance to the material in these areas may be due to the low metabolic rate of infauna over the winter (including bioturbation rates) resulting in thin or patchy RPDs. A plot of reported barge release points for the 1990/1991 disposal season at CLIS indicates that most of the barges released dredged material within 250 m of the CLIS-90 and CS-90-1 buoys (Figure 4-1).

The presence of dredged material at all REMOTS® stations in the main 1991 survey grid reflects the extensive use of this quadrant of CLIS for dredged material disposal over the past few years. A disposal mound has been formed within the 1991 survey area every year since 1987. Previous surveys have noted dredged material disposal away from the intended locations (Germano et al. 1993). At CS-90-1, however, the material was intentionally released at various locations away from the buoy to spread cap material around the CS-90-1 mound.

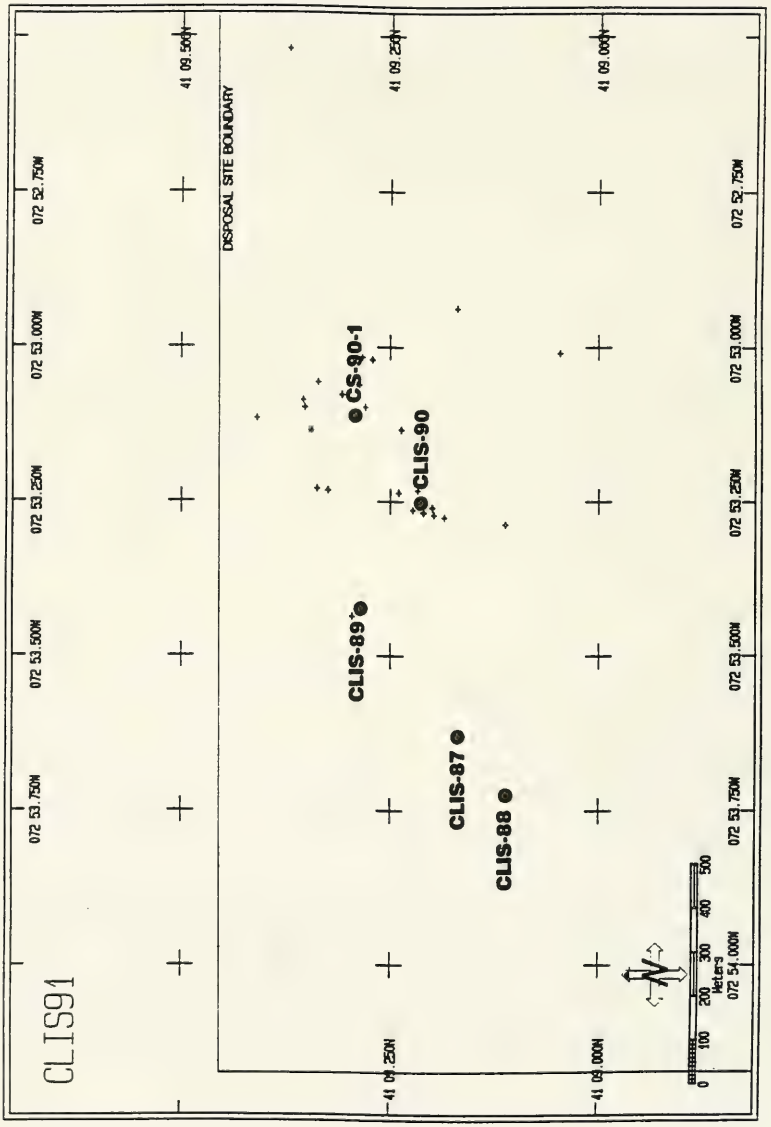


Figure 4-1. Reported barge release points at CLIS during the 1990/91 disposal season

According to log estimates, barges deposited 88,588 m^3 of dredged material at CLIS during the 1990/91 disposal season. A volume calculation based on the depth difference between the July 1990 and June 1991 bathymetric survey at CLIS was 39,503 m^3 of material. The depth difference between 1990 and 1991 includes not only material added to the area during that time but also any compaction of material that has occurred.

Tavolaro (1984) showed that volume estimates based on barge logs overestimate the amount of transported dredged material because of the significant amount of interstitial water associated with the material in the barges ("fluffing"), and the detection limitations of bathymetry. He calculated that "depth difference" volume estimates based on successive bathymetric surveys can be as much as 41% less than the barge log volume estimates. The discrepancy was attributed not only to log inaccuracies (due to limitations inherent in measuring dredged material volumes in the barge) but also to compaction of dredged material on the bottom following disposal and the significant volume of material that is deposited on the flanks of the mounds in layers too thin to be detected acoustically. Applying the 41% factor to the log estimate of 70,624 m^3 for dredged material actually released at CLIS resulted in a corrected barge log estimate of 41,668 m^3. This corrected estimate is 100.5% of the volume of material detected by the bathymetric survey (39,503 m^3).

4.2 CLIS Successional Status

The predicted recolonization status at CLIS was Stage I on the CLIS-90 and CS-90-1 mounds, progressing to Stage III on the inactive mounds. Both the CLIS-90 mound and CS-90-1 mounds had Stage I taxa at the center, but stations around these mounds have apparently retained a Stage III status. Burial of Stage III taxa by thin layers of dredged material does not kill these organisms as they are capable of burrowing upward through the deposited layer to reestablish connection with the new sediment-water interface (Goldring 1964, Kranz 1974).

Stage III organisms were expected at all of the reference areas and inactive mounds. At the reference stations, Stage III taxa predominated with only 2500W-REF, station 100W, having only Stage I infauna. On the inactive mounds, CS-1, CLIS-88, CLIS-89, NHAV-74, and FVP all exhibited Stage III seres. This observation supports convergence between the successional status of old inactive disposal mounds and the ambient bottom. The exception was CS-1, 300E, that had only Stage I. The scattered locations where Stage III was not detected may have been mischaracterized, or a consequence of natural benthic patchiness as also observed at 2500W-REF. The recognition of Stage III seres in REMOTS® photographs depends on the development of subsurface feeding voids. The CLIS 1991 monitoring survey was conducted in the late spring when low sediment temperatures depress the metabolism and feeding rate of Stage III worms (D. Rhoads - pers. comm.). This results in less well-developed feeding voids at depth in sediments and can result in inaccurate successional stage characterization.

At the inactive MQR mound, stations 200N, 200S, 200E, and 100E had only Stage I seres. Because the prevalence of Stage I organisms was higher here than at any other mound, and because of the low RPD values at this area, the apparent lack of Stage III organisms at these locations may indicate, according to the DAMOS tiered monitoring protocol, that further monitoring and management is needed. MQR received contaminated dredged material from such projects as Mill and Quinnipiac Rivers, Black Rock Harbor, and New Haven Harbor between 1982 and 1983, warranting further investigation.

Fresh dredged material has a lack of biological activity and an increased sediment oxygen demand compared to the ambient sediment. This accounts for the significantly shallower RPD depths for the disposal site stations versus the reference stations. Trawling over the sediment surface also may result in loss of the RPD signature by removing sediment at the surface. Some evidence of trawling activity is seen near longitude 72°53.5′ W, stations E5 and D7. Localized areas of oxidized sediment layers greater than three centimeters deep were observed near CS-90-1, CLIS-87, and in the northwest corner of the survey area. Deeper bioturbation by the local infaunal assemblages causes the increased RPD depths in these areas. The mean apparent RPD depths on the NHAV-74 mound are deeper than those at the MQR mound, but this could be attributed to the higher concentration of organic matter in the MQR material.

4.3 CLIS Reference Area Chemistry

The three CLIS reference areas have chemical signatures consistent with this part of Long Island Sound and appear to be suitable as references for monitoring the site. As a set of baseline chemistry data, this report will help in monitoring any future changes in sediment chemistry associated with the reference areas. Data from CLIS reference areas are compared to samples analyzed previously for Cd and Zn by the NED laboratory in 1986 and 1987 (Table 4-1). The values have remained unchanged (Tables 3-2 and 4-1). PAH baseline information at the three reference areas showed concentrations of HMW and LMW PAH compounds were greatest at 2500W, and were similar at 4500E and CLIS-REF (Table 3-3). The higher TOC content at 2500W may have provided additional binding sites for the metals and PAHs analyzed (Table 3-1). This would explain the higher levels of metals and PAHs at 2500W compared to the other two reference areas. Also, 2500W is closer to shore and may receive higher input rates.

Sediment grain size commonly correlates with both metallic and organic contaminants in sediments. Studies of both natural and polluted sediments have demonstrated that higher concentrations of contaminants are usually associated with the fine-grained fraction (silt/clay) of sediments (Forstner and Wittman 1983, Kennish 1992, Pequegnat et al. 1990). Particulate and colloidal organic matter, because of its fine grain size, surface charges, high surface area to volume ratio, and microbial coatings, serve to adsorb or chelate organic and metallic

contaminants. In the following comparisons of CLIS reference area data to regional data, values are normalized to the percent silt and clay content because of the regional variation of grain size and organic content (Table 4-2).

Table 4-1

Metals Concentrations (ppm Dry Weight) in Sediments Collected at NLON, CLIS, and WLIS in 1986 and 1987

Metals (ppm dry weight)	Cd	Zn
NLON-REF		
1986	<3	45 ± 27
1987	ND	NA
CLIS-REF		
1986	ND	110 ± 4
1987	ND	121 ± 9
2500W		
1987	ND	153 ± 7
4500E		
1987	ND	148 ± 10
WLIS-REF		
1986	<3	141 ± 52
1987	ND	135 ± 9
2000S		
1987	ND	99 ± 18
2000W		
1987	ND	215 ± 2

All samples were 0-2 cm in depth.
NA=Not analyzed ND=Not detected

Table 4-2

Comparison of NOAA's NS&T Data with CLIS Reference Areas;
All Concentrations Normalized to the Percent Fine Grained Fraction (Silt and Clay)

NS&T Sites:	ELI	LINH	LIHR	LIHU	LISI	WLI	CLIS		
							2500W	4500E	CLIS-REF
Fine Grained Fraction (%)	7.9	3.2	9.6	46.2	53.6	73.3	87.0	88.0	87.0
Metals									
Cadmium	0.01	0.01	0.04	0.01	0.01	0.01	0.00	0.00	0.00
Lead	2.34	4.10	3.39	0.99	1.02	1.09	0.79	0.64	0.69
Zinc	7.37	7.01	12.11	3.03	3.04	3.22	2.03	1.63	1.53
PAHs									
Low Molecular Weight									
Naphthalene	0.13	0.00	5.64	0.296	5.203	1.791	1.46	0.70	0.46
2-Methylnaphthalene	0.57	0.00	5.82	0.000	1.535	1.236	0.48	0.30	0.17
Acenaphthylene	0.14	0.00	0.00	0.000	0.000	0.730	0.24	0.25	0.17
Acenaphthene	0.00	0.00	4.02	0.000	1.458	0.354	0.18	0.15	0.17
Fluorene	0.00	0.00	2.77	0.000	2.993	0.565	0.30	0.20	0.17
Phenanthrene	0.85	2.19	62.31	2.481	19.536	5.188	2.84	1.97	1.92
Anthracene	0.25	0.00	14.54	0.000	5.908	5.999	0.77	0.51	0.40
Total LMW PAHs	2	2	95	3	37	16	6	4	3
High Molecular Weight									
Fluoranthene	0.73	3.99	126.34	6.706	28.968	10.458	4.87	3.26	2.95
Pyrene	1.81	4.69	157.49	6.643	26.596	9.860	6.97	4.66	4.29
Benzo(a)anthracene	0.85	1.91	46.04	1.869	11.560	6.813	2.57	2.01	1.80
Chrysene	0.89	1.53	58.50	3.047	14.854	7.280	2.99	2.27	2.15
Benzo(b)fluoranthene	0.19	0.00	0.00	0.000	0.000	0.814	3.03	2.27	2.22
Benzo(k)fluoranthene	0.00	0.00	0.00	0.000	0.000	1.541	3.03	2.27	2.22
Benzo(a)pyrene	0.86	3.17	46.38	2.711	11.909	4.873	2.61	2.05	1.99
Dibenzo(a,h)anthracene	0.19	0.00	1.56	0.087	1.727	1.823	0.18	0.15	0.17
Benzo(g,h,i)perylene	0.00	0.00	0.00	0.000	0.000	0.797	2.64	2.16	1.57
Indeno(1,2,3-cd)pyrene	0.00	0.00	0.00	0.000	0.000	0.799	1.56	0.15	0.17
Total HMW PAHs	6	15	436	21	96	45	30	21	20

National Status & Trends Sample Locations:

ELI	Eastern Long Island Sound
LINH	New Haven
LIHR	Housatonic River
LIHU	Huntington Harbor
LISI	Sheffield Island
WLI	Western Long Island Sound

Data collected as part of the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends (NS&T) Program were compared with the CLIS data to provide a frame of reference (Table 4-2). The NS&T Program has collected and analyzed coastal and estuarine sediment data from 300 sites since 1984. Several sites in Long Island Sound that were sampled over the period of 1984-1989 (NOAA 1991) were compared to the CLIS reference area data.

The three sites closest to CLIS, including New Haven Harbor, the Housatonic River, and the East Long Island Sound station (located approximately 50 km east of CLIS) are all sandy sites, with a combined silt and clay percentage of less than 10%. Although these sites are closest geographically, several sites west of CLIS were chosen with more comparable grain size ratios and included with the CLIS comparison (Table 4-2). In addition, all NS&T data are normalized to the fine-grained fraction to compensate for the variation of grain sizes. The correlation between the fine-grained fraction and trace chemical constituents for the NS&T data was higher than with Al or TOC (NOAA 1991). The CLIS data were also normalized to the fine-grained fraction for comparison purposes.

Normalized metals results from the CLIS reference areas were less than metals concentrations measured at the NS&T sites (Table 4-2). All the metals concentrations fall below the "low" category for contaminated sediments suggested by the New England River Basin Commission (Oceanic Society 1982).

Total LMW and HMW PAHs from the CLIS reference areas were also compared to the NS&T sites. PAHs are organic trace contaminants in estuarine and marine environments and consist of carbon and hydrogen arranged in the form of two or more fused benzene rings in linear, angular, or cluster arrangements. They encompass a wide range of chemicals, with the principal sources in estuaries including industrial and municipal wastewater effluents, oil spills, combustion of fossil fuels, commercial and recreational boating activities, riverborne influx, dredged sediments, nonpoint source runoff of materials from terrestrial habitats, and *in situ* diagenesis of organic matter in sediments. The major sources of PAHs in the aquatic environment are petroleum spillage and atmospheric deposition (Kennish 1992).

Low molecular weight PAHs (including naphthalenes, anthracenes, fluorenes, and phenanthrenes) are more soluble, more volatile, and acutely toxic to some organisms, but are noncarcinogenic. LMW PAH compounds originate principally from fresh, unburned petroleum (Kennish 1992). Higher molecular weight PAHs (containing 4 to 7 rings) are carcinogenic, mutagenic, or teratogenic to a wide variety of organisms, including fish and other aquatic life (Kennish 1992, Pequegnat et al. 1990). These compounds are less volatile and have longer residence times in the aquatic environment. They include fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(a)pyrene, and benzo(g,h,i)perylene. HMW PAH compounds are generally derived from fossil fuel combustion (Kennish 1992). It is

currently thought that pyrogenic PAHs are more tightly bound to the particles than petroleum source PAHs (McGroddy et al. 1992).

As PAHs enter water from various sources, they quickly become adsorbed onto organic and inorganic particulate matter, and large amounts are deposited in bottom sediments. Once in bottom sediments, PAHs may undergo biotransformation and biodegradation by benthic organisms. The principal degradative processes for PAHs in the marine environment are photoxidation, chemical oxidation, and biological transformation by microbes and aquatic animals (Kennish 1992).

Total LMW and HMW PAHs normalized to grain size from the CLIS reference areas were higher than three of the NS&T sites (Eastern Long Island Sound, New Haven Harbor, and Huntington Harbor) and lower than three sites (Housatonic River, Sheffield Island, Western Long Island Sound; Table 4-2). Of the six NS&T sites, only two are not nearshore sites: Eastern (ELI) and Western (WLI) Long Island Sound. The fact that the CLIS data fell between these two sites is consistent with the central Long Island Sound location.

There were a few individual PAH compound concentrations measured in CLIS reference samples that were exceptions to the trend shown by the total LMW and HMW values. Benzo(b)fluoranthene, benzo(k)fluoranthene, and benzo(g,h,i)perylene, all HMW PAHs, had higher concentrations in CLIS samples than all of the NS&T sites. Concentrations of acenaphthylene (LMW) and indeno(1,2,3-cd)pyrene (HMW) at the CLIS reference areas were higher than all of the NS&T sites except for WLI (Table 4-2).

4.4 Bottom Water Dissolved Oxygen

Dissolved oxygen concentrations in bottom water at both the CLIS-90 buoy mound and the three reference areas were comparable and high relative to the physiological requirements of macrofaunal organisms (Table 4-3). The objective of the CTD/DO sampling was to assess near-bottom DO concentrations relative to benthic habitat conditions within the reference areas and at the active disposal point. Bottom waters, ranging from 6.3 to 6.77 ppm DO, were all within the aerobic range (Table 4-4). Low DO levels do not affect the behavior or structure of benthic assemblages until the concentration decreases to the hypoxic threshold of 2 ppm (Tyson and Pearson 1991). The absence of hypoxia means there was no regionwide hypoxia effecting the area.

Table 4-3

Progressive Effects of Low Oxygen on Modern Shelf Faunas;
From Tyson and Pearson, 1991

Dissolved Oxygen Range ($mg \cdot l^{-1}$)	Effect on Fauna
2.8 - 1.4	Avoidance and migration by nekton and some mobile epifauna.
2.0 - 1.4	Behavioral responses to stress by stenoxic benthic fauna.
1.4 - 1.0	Emergence of euryoxic infauna.
1.4 - 0.7	Physical inactivity. Duration or severity of conditions exceeds homeostatic capabilities and mortalities.

5.0 CONCLUSIONS

In 1991 the Central Long Island Disposal Site (CLIS) survey revealed that active disposal in 1990–1991 created a stable mound with predicted characteristics. Inactive disposal mounds were also stable and require no special monitoring with the exception of MQR which should be monitored in 1992. The sediment chemistry at the three reference sites and dissolved oxygen levels are consistent with conditions in central Long Island Sound.

The June 1991 monitoring cruise at CLIS was designed to delineate the areal extent of the dredged material and to assess possible environmental impact of past and recent disposal by monitoring the recolonization status of the resident infaunal community. The dredged material did form the distinct mound predicted at the CLIS-90 buoy location. The radius of the mound detected acoustically was not as large as predicted. At CS-90-1, the additional cap material added to the existing mound, and two areas of 20 cm thick material were detected acoustically. The detection of dredged material by REMOTS® photographs increased the observed areal extent of "fresh" dredged material beyond that measured acoustically. However, the dredged material footprint associated with the CLIS-90 mound was difficult to distinguish from older dredged material. Material from disposal activity over the last five years overlaps and makes it difficult to distinguish "fresh" dredged material.

Both the bathymetry and REMOTS® map of fresh dredged material supported the prediction that the CLIS-90 buoy mound would be within a radius of 200 to 250 m. Stage I seres dominated the CLIS-90 buoy mound and the CS-90-1 mound as predicted. Stage III seres dominated the inactive FVP, NHAV-74, CLIS-88, and CLIS-89 mounds as predicted for normal colonization. These data indicate that no further special chemical or physical monitoring is required at these mounds at this time. The MQR inactive mound had four stations with Stage I taxa, and shallow RPD depths were measured around the mound center. Stations E5 and D7, south and west of CLIS-89, were azoic or had low OSI values with evidence of trawling. These areas, MQR, E5, and D7, should be reevaluated in 1992.

Dissolved oxygen levels in the bottom water, and metals and PAH baseline levels in the sediments, were measured at CLIS and the three reference areas to assess environmental quality. The DO levels at CLIS were spatially homogenous between reference areas and the disposal site, showing no hypoxia and varying between 6.3 and 6.77 $mg \cdot l^{-1}$. Results of the metal analyses indicate relatively low levels of Cd, Pb, and Zn, consistent with previous measurements.

PAH compounds were present at all three reference areas. Normalized concentrations of total LMW and HMW PAHs were between concentrations measured at two central Long Island Sound sites (Eastern and Western). Future monitoring at the CLIS reference areas should include PAH sampling to compare with this baseline data to see whether the concentrations of PAHs vary over time.

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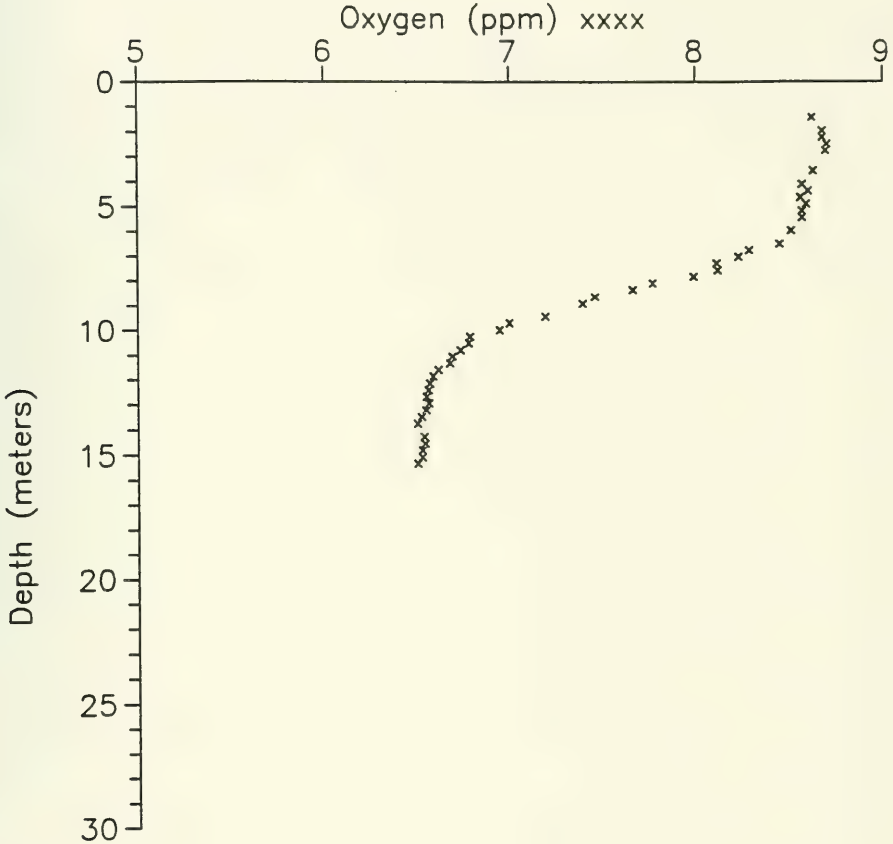
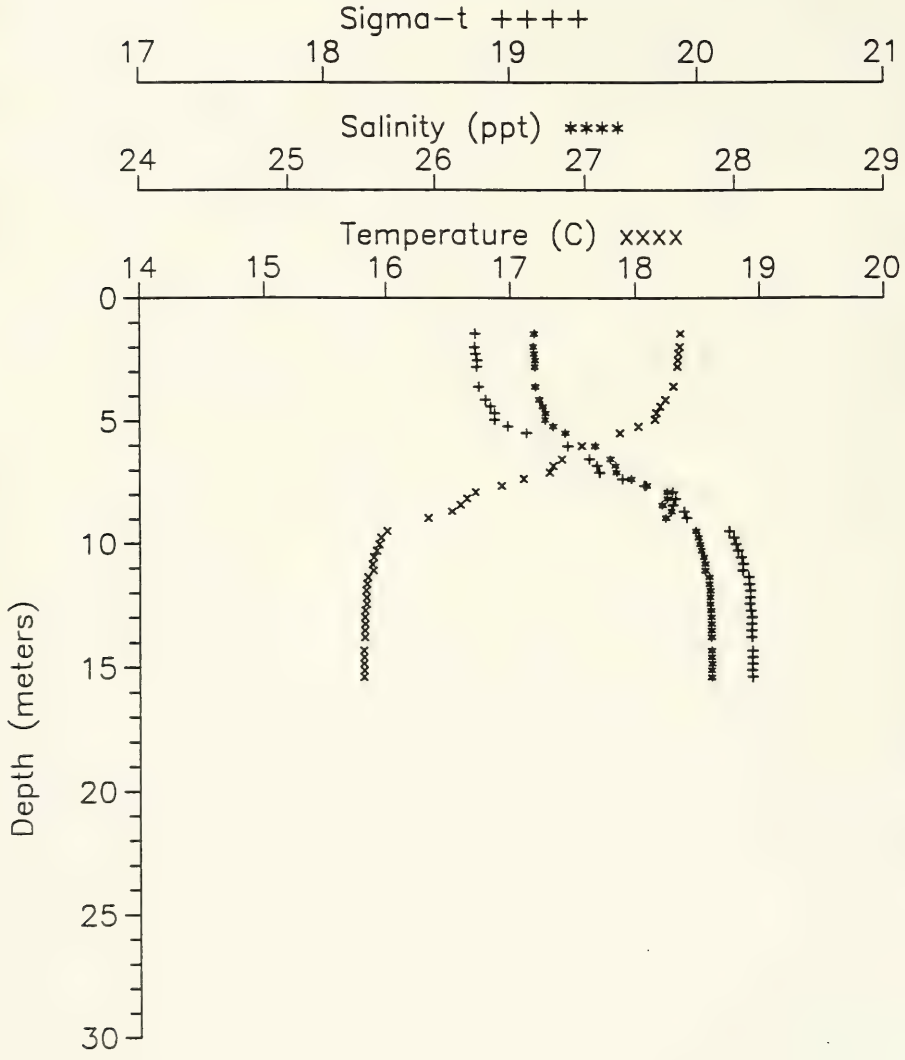
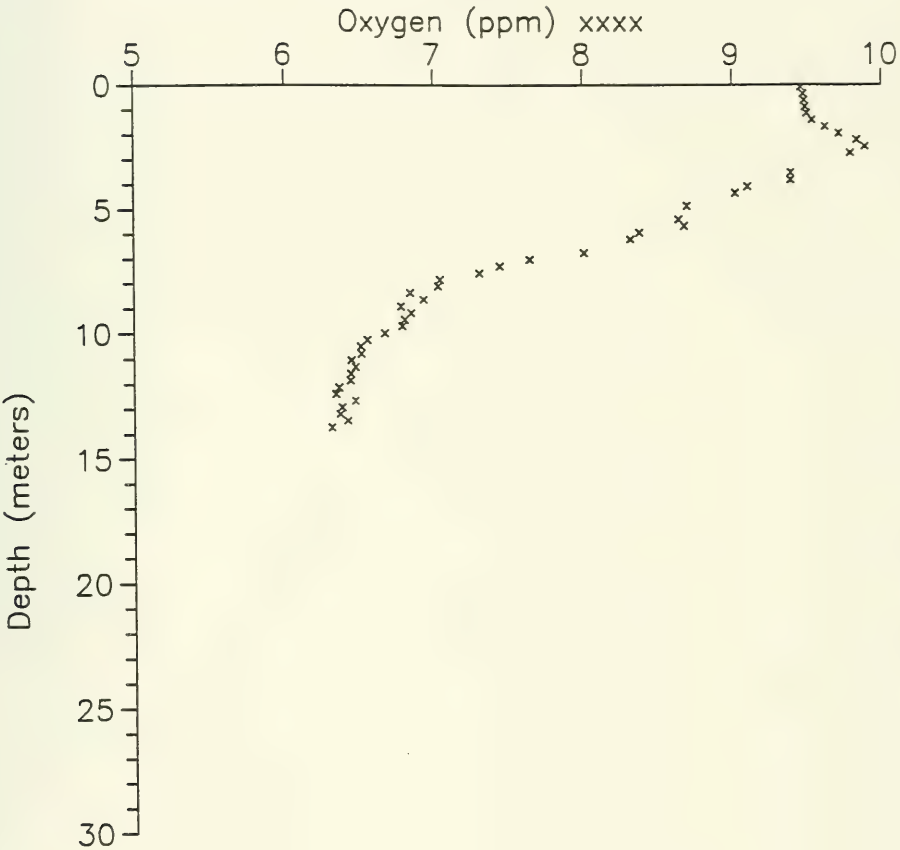
Appendix


Oxygen (ppm) xxxx
5
6
7
8
9
0
5
10
15
20
25
30
Depth (meters)


Sigma–t ++++
17
18
19
20
21
Salinity (ppt) ****
24
25
26
27
28
29
Temperature (C) xxxx
14
15
16
17
18
19
20
0
5
10
15
20
25
30
Depth (meters)

2500W-REF



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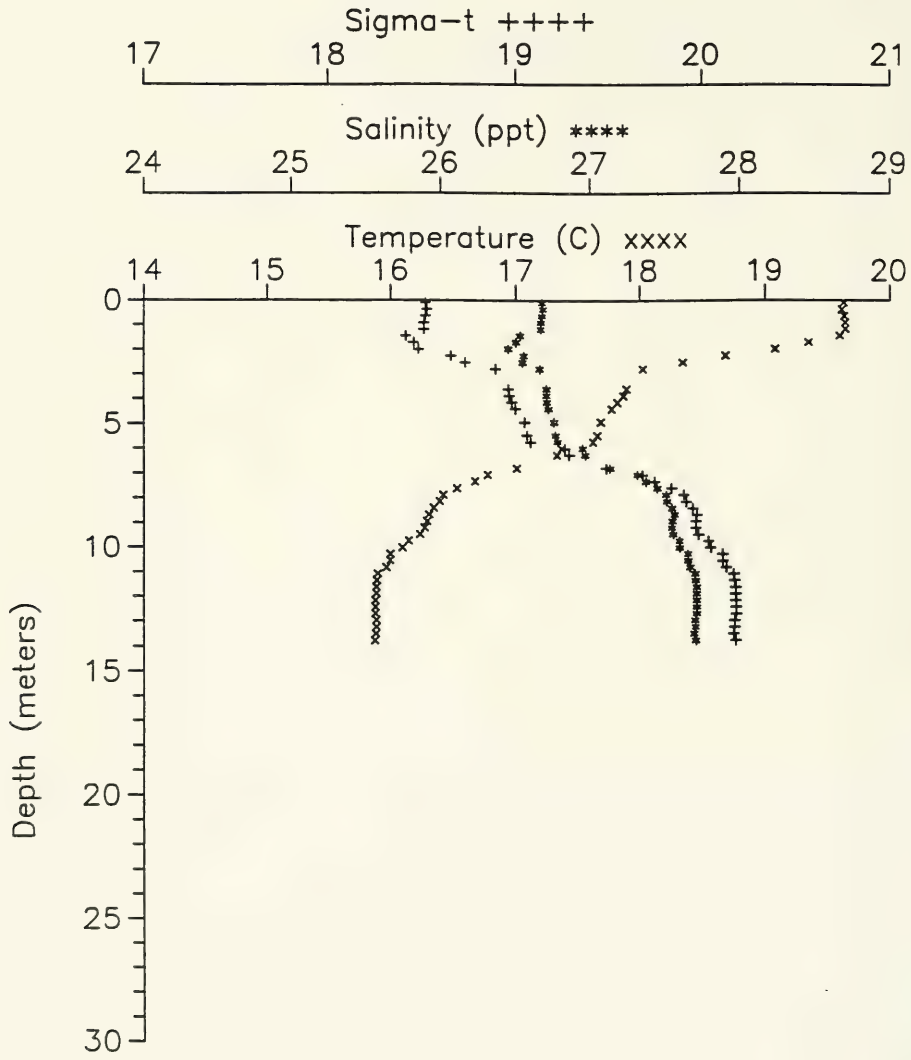
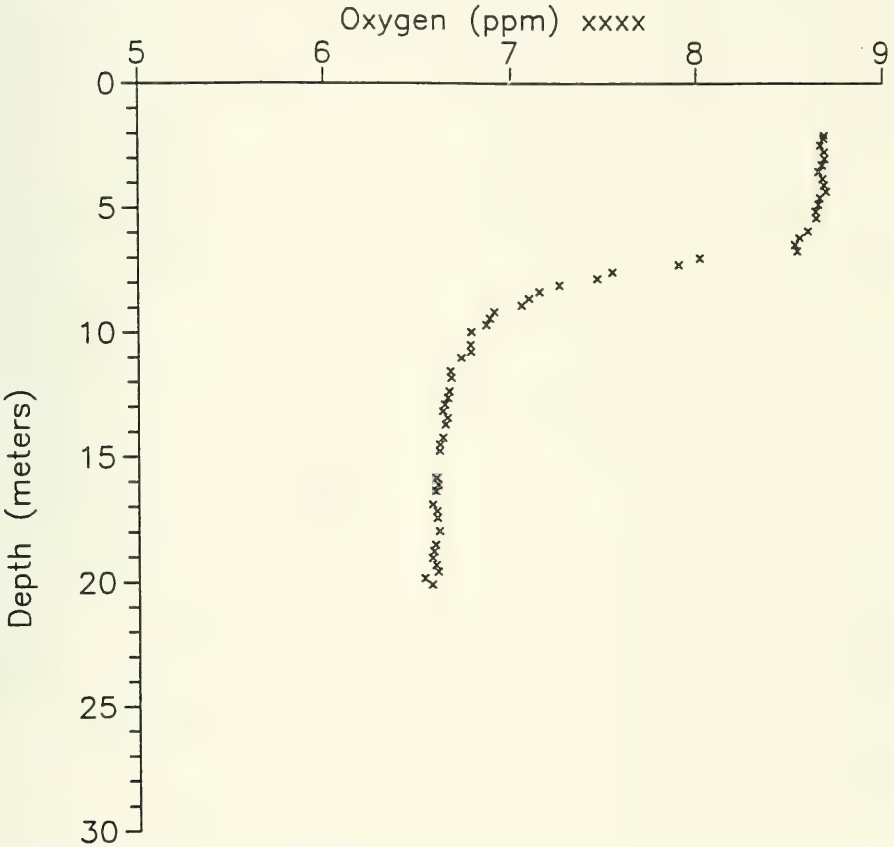

Sigma−t ++++
17
18
19
20
21
Salinity (ppt) ****
24
25
26
27
28
29
Temperature (C) xxxx
14
15
16
17
18
19
20
0
5
10
15
20
25
30
Depth (meters)

CLIS-91

4500E-REF



CLIS-91

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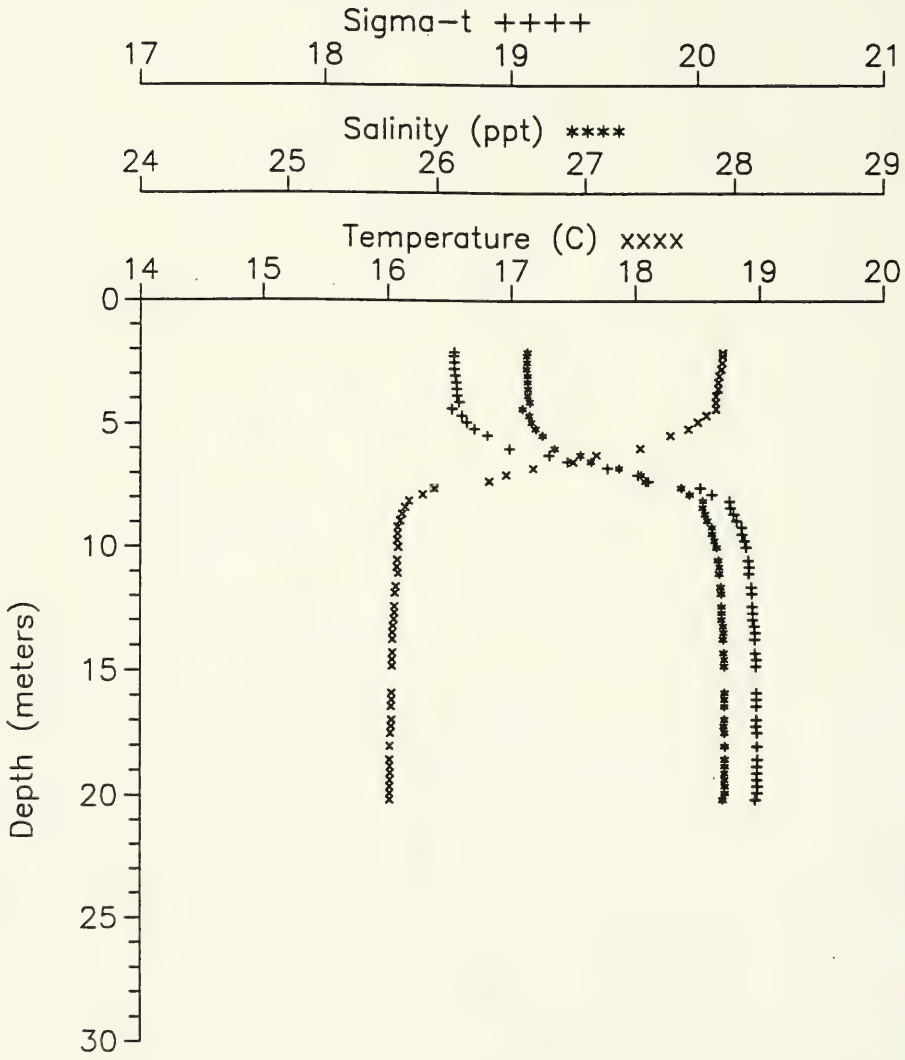
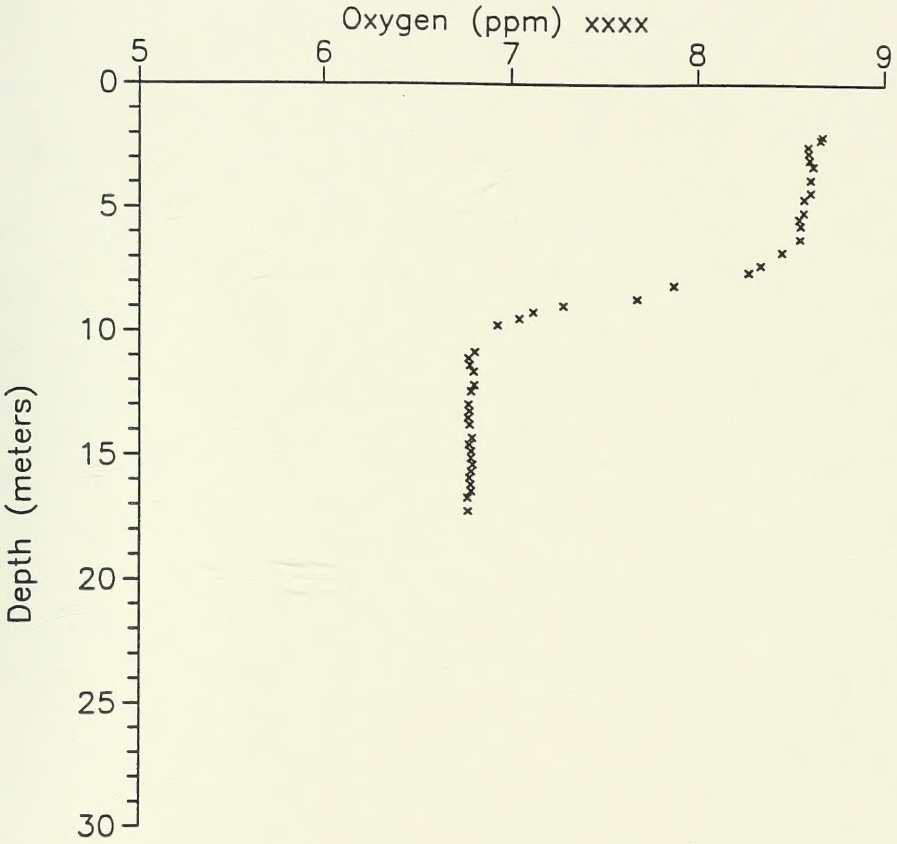
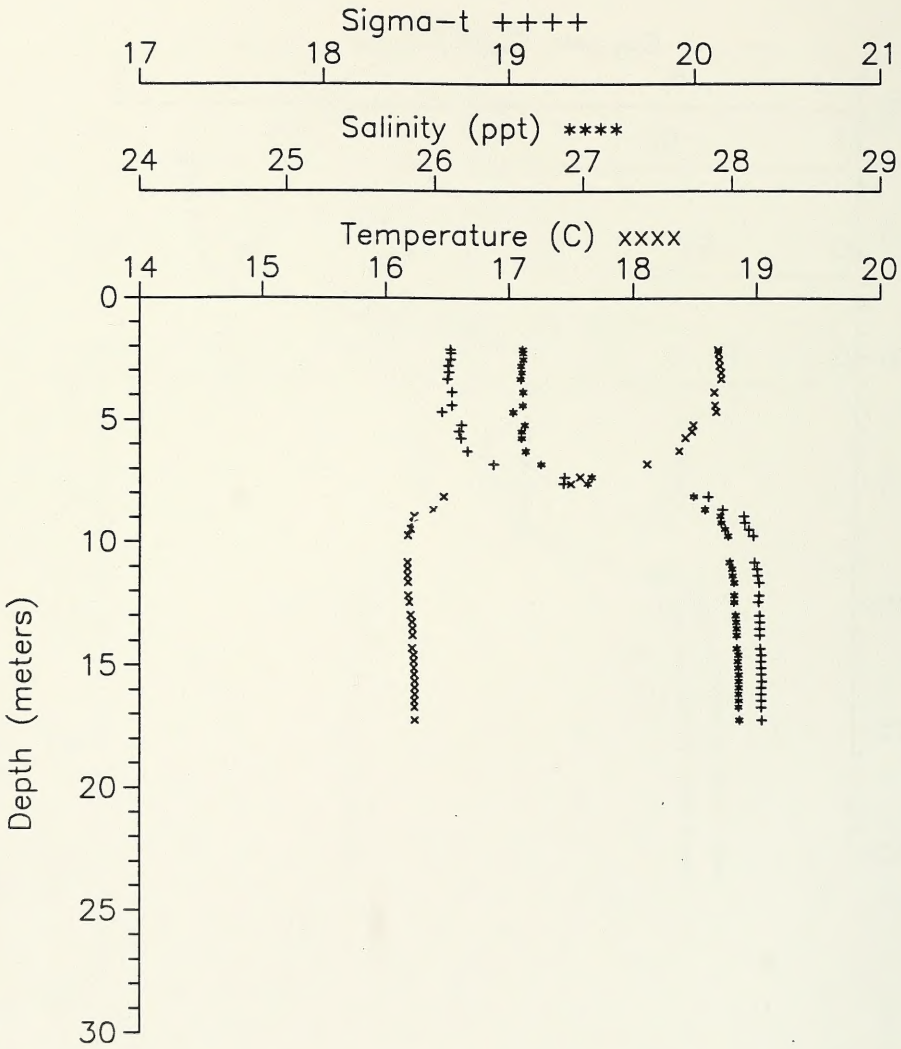



Oxygen (ppm) xxxx
5
6
7
8
9
0
5
10
15
20
25
30
Depth (meters)


Sigma–t ++++
17
18
19
20
21
Salinity (ppt) ****
24
25
26
27
28
29
Temperature (C) xxxx
14
15
16
17
18
19
20
Depth (meters)
0
5
10
15
20
25
30